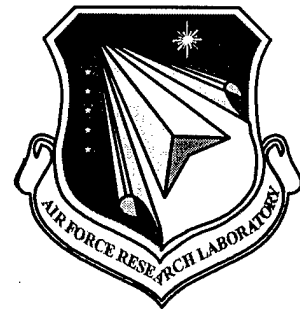


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**Multiple co-substrates for biostimulation of TCE  
degradation**

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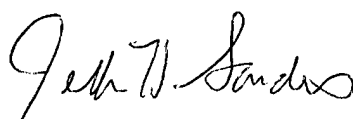
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The objective of this Phase II SBIR project was to test and demonstrate the feasibility of using multiple co-substrates to stimulate *in situ* biodegradation of volatile organochloride compounds (VOCs) including trichloroethylene (TCE), *cis*-1,2 dichloroethylene (DCE) and vinyl chloride (VC). The project also evaluated the use of novel substrate delivery and groundwater capture systems for use during *in situ* biostimulation applications with gaseous cosubstrates. The work involved a field-scale demonstration of propane and oxygen injection to stimulate microbial degradation of VOCs in an aquifer underlying the Lakehurst, NJ Naval Air Engineering Station (NAES)

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## **EXECUTIVE SUMMARY**

### **OBJECTIVE**

The objective of this Phase II SBIR project was to test and demonstrate the feasibility of using multiple co-substrates to stimulate *in situ* biodegradation of volatile organochloride compounds (VOCs) including trichloroethylene (TCE), *cis*-1,2 dichloroethylene (DCE) and vinyl chloride (VC). The project also evaluated the use of novel substrate delivery and groundwater capture systems for use during *in situ* biostimulation applications with gaseous cosubstrates. The work involved a field-scale demonstration of propane and oxygen injection to stimulate microbial degradation of VOCs in an aquifer underlying the Lakehurst, NJ Naval Air Engineering Station (NAES)

### **BACKGROUND**

VOCs are a family of chemicals that have been used extensively as industrial solvents and cleaning agents, and include perchloroethylene (PCE), trichloroethylene (TCE), dichloroethylene (DCE), tri-, and dichloroethane (TCA and DCA) and a number of chemically-related species. The widespread use of VOCs, improper disposal practices, and their chemical properties and stability have led to them becoming common groundwater contaminants throughout the United States and the world.

Biodegradation of many members of the VOC family has been widely studied over the last two decades. In the presence of oxygen, biodegradation is limited to co-metabolic attack whereby the degradative enzyme fortuitously oxidizes the compound without generating sufficient metabolic energy to support growth of the host organisms. Furthermore, the enzymes known to degrade VOCs have evolved to oxidize specific primary growth substrates (e.g.,



methane, propane, toluene, etc.), and are typically produced (induced) only in the presence of those primary substrates.

Bioremediation of VOC-contaminated environments can be facilitated by applying either *ex situ* treatment technologies where degradative bacteria are maintained in engineered bioreactors, or *in situ* treatment technologies where the contaminant is degraded in place. It is generally accepted that direct subsurface biological treatment of contaminated aquifers has distinct economic and risk advantages over above ground treatment for destroying chlorinated solvents in aquifers. For example, pump and treat technologies often require decades to achieve sufficient removal of sorbed VOCs from aquifer and vadose zone materials. Although the pump and treat method does reduce the migration of a VOC plume, the length of time for clean-up creates long term liability, high operating costs, and ultimately the transfer of contaminated material to the ground surface that must be treated and/or taken off-site for disposal. It has, therefore, been the thrust of researchers in bioremediation to develop and implement direct subsurface bioremediation technologies which can rapidly and effectively remediate contaminated sites.

Within the group of *in situ* bioremediation technologies useful for VOCs there is a hierarchy of alternative remedies based upon ease of clean up and cost. The first level of the hierarchy is intrinsic bioremediation whereby indigenous microflora destroy the contaminant of concern before it creates a significant risk to downgradient receptors. This has become a natural first choice of remediation alternatives where applicable because it requires no intervention; just monitoring of contaminant concentrations and modeling of the groundwater flow, natural degradation rates, and the potential risk to down-gradient receptors .

The second choice in the hierarchy, and the subject of this work, is biostimulation which involves the stimulation of indigenous microbial populations to allow them to destroy the target chemicals. In this case, the observation is made that a natural population exists within the contaminated zone, however, specific nutrients, growth substrates, inducers, and/or oxygen are insufficient for microbial activity. Thus, through the introduction of the correct co-substrate, the native degradative population can be stimulated to grow and destroy the target contaminant.

In cases where intrinsic bioremediation or biostimulation do not work because of insufficient or unacclimated bacterial populations or other factors, bioaugmentation of the subsurface potentially can be utilized. Selected strains of bacteria with the desired catalytic capabilities, can be injected directly into the contaminated zones along with any required nutrients to effect the biodegradation of the target chemicals. The added microorganisms can be selected for long-term survival and the ability to occupy a selective niche within the contaminated environment, or they can be added solely as high performance catalysts that rapidly degrade the target contaminant and then perish. In the former case, a stimulant or selective co-substrate can be added to aid survival, and in the latter case, additional microbial catalysts can be added to further the degradation process.

Historically, biostimulation for chlorinated solvent degradation has relied on the *in situ* injection of methane and air to stimulate the activity of chlorinated solvent-degrading methanotrophic bacteria. In a well-publicized field demonstration of the technology, researchers at the U.S. Department of Energy's Savannah River Laboratory (SRNL) installed horizontal wells below and above a TCE contaminated aquifer and then injected both methane and air to stimulate TCE degradation. Estimates of TCE degradation at the site indicated that approximately 700 kg of chlorinated solvents were degraded during the study, and cost estimates have predicted

that the technology can be applied at a cost of approximately \$16 per pound of TCE removed (Terry Hazen, SRNL, personal communication).

In more recent studies, McCarty and co-workers (1998) injected oxygen and toluene into a TCE-contaminated aquifer at Edwards Air Force Base. The system was optimized by installing injection and recovery wells nearly perpendicular to regional groundwater flow, thereby allowing treatment of an 80 m wide portion of the aquifer, and created an *in situ* mixing and biological treatment zone. The system operated efficiently for more than 1 year, resulting in a TCE concentration reduction from 1000 to <50 ppb.

During our Phase I SBIR studies (Steffan, 1997), we evaluated alternative co-substrates for stimulating *in situ* VOC degradation. The substrates were first tested in aquifer microcosms and then in laboratory-scale model aquifers. One approach tested was alternating injection of two VOC degradation-stimulating co-substrates in an attempt to promote the degradative activity of multiple VOC-degrading microbial populations. Another approach involved testing substrates which are typical first oxidation products of primary substrates that induce VOC degradation. For example, propane oxidizing bacteria degrade VOCs and propane via the activity of the enzyme propane monooxygenase (PMO). The first oxidation product produced by propane oxidizing bacteria from propane is propanol. Therefore, we attempted to use propanol as a co-substrate to support VOC degradation.

Most of our Phase I feasibility studies were performed with samples from contaminated aquifers collected from either an industrial site in central Wisconsin, an industrial site and location of another Phase II SBIR demonstration project in central New Jersey, or a DoD facility in Delaware. Based on our promising Phase I results, the Delaware site was selected for this Phase II demonstration project. During the initial 6 months of this project, work (including

laboratory studies) continued towards field-scale demonstration at the Delaware site, and demonstration plans and system designs were prepared for that site. Unfortunately, our chosen demonstration location at the Delaware facility became unavailable due to logistical changes at the base, and selection of a new location was required. Because of our inability to locate suitable alternative test locations at the Delaware facility, test sites were sought at other facilities. An alternative test site was selected at the Lakehurst Naval Air Engineering Station (NAES), and the test system was designed, installed and operated concurrently with the performance of laboratory-scale microcosm and column studies designed to obtain optimization data for the operating field-system.

## **SCOPE**

The primary goals of this technology development project were to: (1) evaluate *in situ* biostimulation as a remedial alternative for VOC-contaminated aquifers, (2) identify co-substrates that could be used to stimulate VOC degradation in a contaminated aquifer, (3) test the utility of multiple co-substrates to improve long-term degradation of VOCs, (4) evaluate the use of a modified groundwater circulation system for creating an *in situ* treatment zone for VOCs, and (5) evaluate the use of diffusive membranes as a mechanism for safely delivering gaseous substrates (oxygen and propane) to the subsurface treatment zone.

## **RESULTS**

Results of this study demonstrated the utility of the recirculation system for creating an *in situ* treatment zone and distributing gaseous cosubstrates throughout the subsurface. Furthermore, the use of membrane diffusion devices allowed introduction of gaseous substrates to the saturated zone of the subsurface without stripping of the volatile target contaminants.

No significant VOC degradation was observed in microcosm, column, nor field experiments. Enrichment culturing and selective plate counting suggested that the aquifer did not have an adequate resident population of VOC-degrading propanotrophs to support a biostimulation-based remedial approach for the site. Consortia that could be enriched on 2-propanol or 1-butanol did not degrade the target contaminant. Additionally, seeding the model column aquifers with the exogenous propanotroph strain ENV425 did not enhance biodegradation of the target VOCs, even if the groundwater pH was adjusted to within an optimum range. The addition of a different bacterial culture (*Burkholderia* sp. ENV735) that grows on toluene and degrades VOC did support enhanced VOC degradation in the same columns. These results suggest that the groundwater chemistry or sediment geochemistry is incompatible with the growth and activity of propanotrophs, but the exact cause of the apparent inhibition was not successfully elucidated.

## **CONCLUSIONS**

Results of this study demonstrate that the recirculating groundwater capture system coupled with *in situ* diffusive membranes provides a suitable method for introducing gaseous substrates to the subsurface and creating an *in situ* biotreatment zone. The results also demonstrate that some aquifers may be devoid of suitable co-metabolic VOC-degrading bacteria populations, and that the introduction of propane and oxygen to these aquifers may not stimulate *in situ* VOC degradation within a suitable time frame to facilitate timely remediation of the sites. Up-front laboratory treatability testing is required to determine the utility of *in situ* biostimulation at selected sites, and in some cases seed cultures will be needed to support *in situ* co-metabolic VOC degradation. The results of the field demonstration also show that the approach used during this project can provide a cost-effective treatment alternative when applied

at a suitable site. Co-substrate costs are low, and the recirculation system allows treatment of a relatively large portion of a contaminated aquifer with the installation of only a few wells. The amount of wells required can be further reduced by using alternative co-substrate injection systems (e.g., push probe-installed sparging points that have a greater radius of influence) where concerns about fugitive releases of co-substrates are not great.

## **RECOMMENDATIONS**

Based on the results of this study, it is clear that propane biostimulation is not suitable for *in situ* VOC degradation at all VOC-contaminated sites. However, it is recommended that the utility of this technology be further evaluated and considered because of its relatively low cost and ease of application. Furthermore, it is recommended that up-front treatability testing be performed at all sites prior to application, and that the use of bacterial seeding prior to substrate injection be evaluated as a modification of the technology for sites without an adequate resident VOC-degrading microbial population.

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## 1. INTRODUCTION

Volatile organochloride compounds (VOCs) including perchloroethylene (PCE), trichloroethylene (TCE), and dichloroethylene (DCE), have been used extensively as industrial solvents and cleaning agents throughout the DoD, DoE, and the private sector, and they are now primary pollutants at many government and private sites. This project aimed at demonstrating an innovative aerobic biostimulation approach for remediating VOC-contaminated sites.

The widespread use of VOCs, improper disposal practices, and their chemical properties and stability have led to them becoming common groundwater contaminants at many DoD facilities throughout the United States and the world. Currently, available remediation technologies have had only minimal success in treating many sites contaminated with these chemicals. The use of cost-effective innovative technologies to remediate VOC-impacted groundwater at DoD facilities in part addresses the DoD's environmental requirements to protect communities, recover land resources, and reduce the DoD's annual environmental restoration expenditures.

Direct subsurface (*in situ*) biological treatment has distinct economic and risk advantages over physical treatment (*e.g.*, pump-and-treat [P&T] or air sparging) because they destroy the VOCs in place. Aerobic biostimulation is one *in situ* technology that can be applied when other technologies are not appropriate or effective. For example, P&T technologies often require decades to achieve sufficient removal of sorbed VOCs from aquifer materials. Although P&T can control the migration of a plume, the length of time for clean-up creates long term liability, high operating costs, and ultimately the transfer of contaminants to the ground surface where they must be treated and/or taken off-site for disposal. Likewise air sparging can be ineffective

when an aquifer is striated or confined by clay lenses which divert air in an unpredictable manner. In both cases, however, aerobic biostimulation may provide an effective remediation alternative. For example, a biostimulant can be injected at multiple levels between clay lenses or layers to allow multilevel treatment. It has, therefore, been a research thrust to develop and implement an *in situ* biostimulation technology, which can rapidly and effectively remediate contaminated sites.

The work conducted under this project builds upon existing biostimulation technologies (*i.e.* the injection of toluene or methane) to provide a remediation approach where the use of existing technologies is not practical or acceptable. For example, many states or regulatory districts will not currently allow the injection of toluene into groundwater because of its toxicity and existing groundwater regulations. Similarly, many sites do not provide ready access to natural gas (methane) lines. The use of substrates like butane and/or propane can overcome some of these limitations. They are less toxic than toluene, and both, unlike methane, can be transported and stored at sites in tanks in liquid form.

## **1.1 Technology Description**

Several classes of microorganisms are able to degrade TCE under the proper conditions. TCE can be biodegraded by aerobic bacteria that oxidize aromatic hydrocarbons (Nelson et al., 1987, 1986, 1988; Wackett and Gibson, 1988; Winter et al., 1989), methane (Fogel et al., 1986; Little et al., 1988), ammonia (Arciero et al., 1989), and propane (Wackett et al., 1989). All of these bacteria initiate the degradation of growth substrates and TCE by incorporating atmospheric oxygen through the action of enzymes known as oxygenases. Typically, the oxygenase enzyme

systems are only induced by growth in the presence of the specific hydrocarbon (*e.g.* toluene monooxygenase [TMO] is induced by toluene). The soluble methane monooxygenase (sMMO) of methanotrophs (Fogel et al., 1986; Little et al., 1988), and ammonia monooxygenase of *Nitrosomonas europaea* (Arciero et al., 1989), also oxidize TCE. Soluble MMO has been shown to degrade the greatest range of chlorinated solvents of the known oxygenases. Until recently, it was the only oxygenase known to degrade TCE (Fogel et al., 1986; Little et al., 1988), DCE (Arciero et al., 1989; Fogel et al., 1986), TCA (Henson et al., 1988; Oldenhuis et al., 1989), chloroform, and several hydrohalocarbons (HCFCs and HFCs; DeFlaun et al., 1992).

Recent studies by Envirogen scientists, through the funding of a National Science Foundation (NSF) Phase I SBIR project (NSF award # III-9361804), demonstrated that the propane monooxygenase (PMO) of *Mycobacterium vaccea* JOB5 (Perry, 1968) can oxidize a wide range of hazard chemicals, similar to that of sMMO. In addition, PMO and sMMO showed a comparable TCE degradation rate. An advantage of working with JOB5 versus methanotrophs is that it can be grown on rich media or on minimal media with a variety of substrates such as isopropanol, and butanol.

The requirement for a co-oxidative substrate in TCE metabolism partially explains the recalcitrance of this molecule in the environment and presents some challenges for a biological treatment process. Co-substrates that are degraded by the same enzymes that attack the chlorinated solvents present a conflicting relationship between the two substrates. For example, phenol is required for sustained degradation of TCE by *Pseudomonas cepacia* strain G4 (Nelson et al., 1987). However, phenol inhibits, by competitive inhibition, the degradation of TCE

(unpublished data). Similarly, the toluene monooxygenase enzyme system of *P. mendocina* KR1 can degrade TCE for extended periods only if toluene is present in the reaction mixture, but low concentrations of toluene inhibits TCE degradation by this enzyme system (Winter et al., 1989). Wackett and co-workers have also observed inhibition of TCE degradation by propane in studies with *M. vaccea* JOB5 (Wackett et al., 1989).

An often-overlooked problem in treating solvent-contaminated sites is that individual solvents rarely occur as a single contaminant, but rather as mixtures. Although numerous aromatic-degrading bacteria can degrade TCE (see above), only recently have Envirogen scientists identified that some toluene oxidizers can also attack some saturated solvents (1,2-DCA and chloroform; McClay et al., 1996). During typical remediation efforts with aromatic-degrading strains, co-contaminants may go untreated, or more importantly, they may inhibit degradation of a target contaminant due to their toxicity. Only the sMMO, and now PMO, are known to degrade TCE, 1,1,2-TCA, chloroform, and several other saturated halogenated compounds.

In this aerobic biostimulation demonstration, we evaluated the addition of gaseous co-substrates to enhance *in situ* biostimulation. Because the same enzyme that is used by degradative organisms to oxidize primary growth substrates also oxidizes VOCs, VOC degradation is subjected to competitive inhibition. For example, toluene-oxidizing bacteria degrade TCE via a toluene monooxygenase enzyme, which is also required for growth on toluene. Therefore, in the presence of toluene, TCE degradation is inhibited by competition with toluene at the active site of the degradative enzyme. Others have attempted to overcome this limitation by pulsing substrates so that TCE degradation proceeded as the primary substrate is depleted.

During this demonstration our substrate injection system operated as a groundwater extraction and re-injection system, oriented perpendicular to the direction of groundwater flow to maximize treatment area. Groundwater was extracted from an existing extraction well, and re-injected by two injection wells. This approach allows a relatively large treatment zone with a minimum number of pumping wells (McCarty et al., 1998).

Aerobic bioremediation processes typically consume dissolved oxygen at a greater rate than background conditions can supply. However, rather than amend recirculating groundwater with oxygen, gas injection wells were used for pulsed injection of oxygen, as well as for injection of the gaseous substrate propane. Injection of oxygen in this manner minimizes the likelihood of severe maintenance problems associated with biofouling and metals precipitation at the groundwater injection wells where radial flow conditions limit the capacity for fouling. Gas injection rates were adjusted to maximize partitioning of these gases into the groundwater, while minimizing stripping of VOCs from groundwater. Separate liquid injection wells were constructed to allow addition of liquid substrates, such as propanol and butanol, into the groundwater within the treatment zone. Vadose zone probes were used to monitor concentrations of VOCs, oxygen, and substrate gases in the test plot.

Groundwater monitoring wells within the treatment zone, as well as those upgradient and downgradient of the area, were used to monitor the distribution of dissolved oxygen, co-substrates, and target VOCs. The collected data was used to optimize the rate of injection in an



attempt to achieve the goal of biostimulation within the treatment zone while minimizing the impact to downgradient natural attenuation processes of the contaminants.

## **1.2 Development Status**

This section presents the current development status of *in situ* aerobic biostimulation technology. Development status is described in terms of demonstration history, successful applications, and previous acceptance.

Historically, biostimulation has relied on the *in situ* injection of methane and air to stimulate the activity of chlorinated solvent-degrading methanotrophic bacteria. In a well publicized field demonstration of the technology, researchers at the Savannah River Laboratory installed horizontal wells below and above a TCE contaminated aquifer (Lombard et al., 1994). Methane and air were injected into the lower well and a vacuum was applied to the upper well to recover TCE stripped from the groundwater. The greatest rates of TCE degradation were achieved when methane was pulsed into the aquifer (Hazen et al., 1994). Total numbers of methanotrophic microorganisms remained relatively low throughout the study, but increased significantly after the addition of gaseous nitrogen and phosphorous (Brockman et al., 1995). Estimates of TCE degradation at the site indicated that approximately 700 kg of chlorinated solvents were degraded during the study, and cost estimates have predicted that the technology can be applied at a cost of approximately \$16 per pound of TCE removed (Terry Hazen, SRNL, personal communication).

In another set of studies, continuous injection of methane or propane in the presence of oxygen was shown to lead to excessive microbial growth at the injection site, increasing the potential for clogging and reducing the formation of a uniform biomass distribution. Semprini and McCarty

(1991) showed that this limitation could be overcome by pulsed addition of methane and oxygen into the saturated zone. Because methane utilization requires the simultaneous presence of methane and oxygen, bacterial growth can only occur at the interface between the injected electron acceptor and donor where they are brought together through dispersion mixing. The longer the pulse cycle, the further methane and oxygen could travel before mixing and consumption resulting in a more uniform biomass distribution (Roberts et al., 1990). Indigenous microorganisms stimulated by methane or propane (Semprini & McCarty, 1992, Semprini et al., 1994) had the capacity to co-metabolically transform vinyl chloride (VC), *t*-DCE, *c*-DCE and TCE. In both cases, oxidation of the chlorinated solvents were closely coincident with the concentration oscillations of the injected co-substrate and followed a mathematical model simulation using competitive inhibition kinetics and rate-limited sorption.

During laboratory studies by Dolan and McCarty (1995a,b) the substrate pulse duration also effected VC degradation rates. If short pulses (6 hr) were used, VC degradation was slow, presumably due to competitive inhibition by residual methane. If 12 hr. pulses were used, high rates of VC degradation were achieved.

In the most recent field study of biostimulation, McCarty and co-workers (1998) injected oxygen and toluene into a TCE-contaminated aquifer at Edwards AFB. Installing injection and recovery wells nearly perpendicular to regional groundwater flow optimized the system. The well orientation allowed the treatment of an 80 m wide portion of the aquifer, and created an *in situ* mixing and biological treatment zone. The system operated efficiently for more than 1 year, resulting in a TCE concentration reduction from 1000 ppb to <50 ppb.

### 1.3 Description of Technology Process

The demonstration system used in this study operated as a groundwater extraction and re-injection system, oriented perpendicular to the direction of groundwater flow to maximize the treatment area. Groundwater was extracted and re-injected at approximately 25 gallons per minute (gpm) creating a groundwater capture zone of approximately 120 feet in width. A model simulation showing groundwater flow conditions under this pumping scheme is presented on Figures 1.3.1 and 1.3.2. Co-substrate (*e.g.*, butanol and propane) and oxygen could be injected at points located between the extraction well and injection wells to create a treatment zone approximately 45 feet in width (Figure 1.3.3). This approach creates a relatively large treatment zone with a minimum number of pumping wells. Groundwater was maintained within the treatment zone for 6 to 16 days.

Separate gas injection wells were used for pulsed injection of oxygen and the gaseous substrate propane (Figure 1.3.4). The gas injection wells employed an innovative bubble-less gas diffuser tube that extended the entire screened length of the injection well (approximately 20 feet). The diffuser tubes were constructed of a permeable silicone tubing that allowed for excellent distribution of injected gas through out the entire saturated thickness of the treatment zone (Figure 1.3.5). The bubble-less diffuser tube gas delivery system eliminates any potential loss of VOC through volatilization that normally occurs in typical sparging type gas delivery systems. Vapor probes were also used to monitor concentrations of VOCs, oxygen, and substrate gases in the test plot to confirm that stripping of these compounds was not occurring and to verify that an explosive environment was not created in the vadose zone overlying the treatment zone.

Liquid substrate injection wells screened over the entire saturated thickness of the treatment zone (approximately 20 feet) were designed to deliver liquid substrates through out the treatment zone. The use of separate injection wells to deliver oxygen, gaseous substrates, and liquid substrates and separate injection wells to re-circulate groundwater through the treatment zone reduced the potential for biofouling of individual injection points.

Groundwater monitoring wells were used to monitor distribution of injected oxygen and co-substrates and the concentration of target VOCs throughout the treatment zone as well as up-gradient and down-gradient of the treatment zone.

## **2. MATERIALS AND METHODS**

### **2.1 Laboratory Studies**

**2.1.1. Microcosm Studies.** During Phase I of this project simple enrichment culturing experiments were performed to identify potential co-substrates for stimulating TCE biodegradation (Steffan 1997). Aquifer materials from two different sites were evaluated. In one set of site samples the addition of 1-butanol stimulated the rapid growth of indigenous bacteria, whereas the addition of 1-or 2-propanol, propane, methane, butane, methanol, and 2-butanol did not result in rapid growth. Subsequently, the addition of 1-butanol to microcosms developed from the site resulted in the best TCE degradation of the substrates tested. In the other aquifer materials both 2-butanol and isopropanol resulted in rapid growth in enrichments, and they stimulated TCE-degradation activity in microcosms. These results suggested that such enrichments and microcosm studies will provide a simple method for assessing which co-

substrates will stimulate TCE degradation in a selected aquifer. In addition to providing a rapid screening method for desirable substrates, microcosm studies are useful to 1) confirm and/or modify model assumptions made regarding oxygen and co-substrate utilization rates, 2) confirm or determine optimum co-substrate feeding regimes, 3) assess acclimation periods to be expected in the field study, 4) to evaluate secondary co-substrates for use in field-scale multiple co-substrate evaluations, and 5) to address any problems that may affect the field demonstration, or that may arise during the field demonstration (e.g. product or substrate toxicity).

For preliminary evaluation of biostimulation substrates, aquifer sediments and groundwater were collected from the Lakehurst demonstration site. Sediments were collected from the drill auger during extraction well, reinjection well, and monitoring well installation. Samples were placed in sterile 1-L jars, and the jars were placed on ice for immediate transport to the laboratory. Likewise, groundwater was collected from well LK, placed in sterile 1-L jars and transported on ice to the laboratory.

Enrichment culturing was performed to determine the presence or absence of VOC-degrading microbes in the Lakehurst aquifer. Sediment and groundwater samples were added to flasks containing basal salts medium (BSM; Hareland et al., 1975) and a test growth substrate (1-butanol, 2-butanol, 1-propanol, 2-propanol [100 mg/L], or propane or butane [25% v/v in O<sub>2</sub> headspace]) and incubated at either 15°C or 25°C. The flasks were monitored for utilization of the test substrate and apparent changes in cell density. Because of turbidity caused by the soil material, growth in the primary enrichments was difficult to assess. Therefore, all of the enrichments were sub-cultured into fresh BSM and substrate after 4 weeks of incubation, and the

enrichment was continued. Periodically, samples of the primary and secondary enrichments were analyzed for TCE degradation activity by using a standardized bottle assay as previously described (McClay et al., 1995).

Microcosms were constructed by placing 50 g of composite soil collected at 45 to 60 feet bgs and 55 ml of groundwater into 125-ml serum vials. Triplicate microcosms received no additions (NA 1,2,3), 1 ml 7.4%  $\text{HgCl}_2$  and 1 ml 15% sodium azide (Kill 1,2,3), 50 ppm isopropanol (Pol 1,2,3), 50 ppm isopropanol and Kgrow fertilizer (Pol+K-G 1,2,3), 2 mg propane (Pane 1,2,3), or 2 mg propane and Kgrow fertilizer (Pane+K-G). Kgrow fertilizer is a soluble fertilizer purchased from K-Mart department stores. Kgrow was added from a 100X stock solution to generate final nutrient additions of 3 mg/L phosphate, 3 mg/L N as ammonia, and 2.5 mg/L N as urea. The serum bottles were sealed with Teflon-lined septa and incubated at 15°C on their sides on a rotary shaker. To sample the bottles the septa were pierced with an 18-ga. needle and a sample of the slurry was removed and placed in a VOA bottle. The solids were allowed to settle and a portion of the liquid was analyzed by GC/MS using EPA method 8260. The VOA vials from samples receiving propane were heated to 80 °C to partition propane into the headspace, and a portion of headspace gas was analyzed for propane on a GC with a thermal conductivity detector.

**2.1.2. Column Studies.** In addition to microcosm studies, concurrent studies were performed with larger model aquifers constructed in glass columns. The column aquifers were designed to allow modeling of TCE degradation under a regime of multiple co-substrate feeding. These prolonged studies also would allow us to optimize substrate pulse duration and to select substrate

combinations that result in the greatest rate of TCE degradation and the most efficient utilization of co-substrate and oxygen. Furthermore, they allow us to evaluate the effect of prolonged operation on aquifer plugging, to evaluate mechanisms for managing potential plugging problems during field operation of a biostimulation system, to evaluate changes in substrate and oxygen requirements as microbial biomass increased, and to develop preliminary models for optimization of the field system.

Large-scale model aquifers were constructed from glass chromatography columns (4.6 cm ID x 50 cm; Kontes, Vineland, NJ (Figure 2.1.2.1). Columns were designed to allow water sampling above the soil, 2 cm and 25 cm below the surface of the soil, below the columns, and from ground water reservoirs. An upward flow of groundwater (0.5 ml per min.) was supplied by a peristaltic pump (Model no. 7520-35; Cole-Parmer Instrument Co., Chicago IL) and 1/16 inch Norprene tubing (Scientific Products, McGaw Park, IL). The columns were maintained at 14 °C by wrapping them with insulated copper coils filled with recirculating chilled ethylene glycol (50%). A miniature oxygen probe (OM-4 oxygen meter and MI-730 electrode; Microelectrodes, Inc., Bedford, NH) could be mounted in the effluent stream at the top of each column to determine dissolved oxygen concentration.

Each of 4 aquifer columns received an average of 2400 g of composite wet soil (0.17 g H<sub>2</sub>O/g wet soil) collected from 45' to 65' bgs in the Lakehurst aquifer. To pack the columns they first received 54 mls of site groundwater, and the soil was then added to the top of the column to displace the water. After all of the soil was added to the column, the water was left in the column until the remaining fine particles settled on the top of the soil column. Although this

method allowed some separation of the silt and clay material from the soil, repeated experimentation demonstrated that this was the best method to avoid void spaces and groundwater channeling in the columns. Because the aquifer soil was composed primarily of sand, the loss or re-partitioning of a small amount of fine soil particles was expected to have a minimal effect on the operation and performance of the columns. The pore volume of the columns was approximately 407ml.

Groundwater to be passed through the columns was placed in a 9-L carboy, and oxygen and propane were added to the groundwater by using a silicone tubing diffuser. The diffuser consisted of a 24" length of 1/4" ID silicone tubing. The silicone tubing was attached to a length of copper tubing that was attached through a regulator to a tank of either oxygen or propane. Gas pressure on the tubing was maintained at 7.5 psi, which was determined experimentally to provide sufficient gas concentrations in the water without bubbling. A draw tube was inserted through the stopper and connected to the bottom of each aquifer column, and groundwater flow through the tubing ("feed line") was controlled with a peristaltic pump. TCE was added to the feed line by using a syringe pump and concentrated stock solution (240 mg/L) held in gas tight syringes. The groundwater feed line had a flow rate of approximately 20 ml/min and the TCE feed rate was set at 0.125 ml/h. After 84 days of operation the flow rate to the column was reduced to approximately 6 ml/min to extend the hydraulic residence of the groundwater. The concentration of propane, oxygen, and TCE entering the column was determined by removing and analyzing a groundwater sample from a sampling port immediately before column inlet. Groundwater samples also were removed from the top of the columns and analyzed for TCE, and co-substrates.



Two separate operating conditions were evaluated during the column study. Columns 1 and 2 were operated at a pH of ~7, whereas columns 3 and 4 were operated at the ambient pH of ~5. These pH ranges were chosen to evaluate the effect of average ambient pH (i.e., pH ~5) on biodegradation, and the potential effect of pH neutralization (i.e., pH 7) on overcoming any inhibition caused by low pH. Additionally, two bioaugmentation experiments were performed to evaluate the potential for improving VOC degradation via aquifer seeding. In the first experiment column 1 was seeded with a pulse of 100 ml of a  $1 \times 10^9$  CFU/ml culture of the propane oxidizing strain ENV425 (Steffan et al., 1997). Columns 2 received a similar pulse of groundwater. In the second experiment columns 1 was seeded with a pulse of 20 ml of a  $1 \times 10^{10}$  CFU/ml culture of the adhesion deficient, VOC-degrading, toluene oxidizing strain ENV435. Strain ENV435 degrades chlorinated solvents rapidly and was used successfully to treat chlorinated solvents during an in situ field demonstration of aerobic bioaugmentation (Steffan et al., 1999), and during a commercial-scale remediation project (Envirogen, unpublished). Both field applications were performed in New Jersey aquifers, but both aquifers had near neutral pH levels. Column 2 received a similar volume of BSM medium. Groundwater samples for TCE analysis (1 ml) were collected from both the top of each column, and from each ground water reservoir or feed line immediately up-stream of the column influent by using gas-tight syringes (model no. 1001 LLT; Hamilton, Reno, NV). The samples were placed into 2-ml glass auto-sampler vials (Scientific Products, McGaw, IL) and capped with 11 mm crimp-seal Teflon-lined red rubber septa (Supelco, Bellefonte, PA). TCE measurements were made by head space analysis. Briefly, TCE was allowed to equilibrate between the liquid and gas phases within the auto sampler vials. A portion of the headspace gas (10  $\mu$ L) was then collected from the bottle

with a gas tight syringe and injected into a Varian 8200 gas chromatograph equipped with an ECD detector (Vocol 30 m x 0.53 mm ID fused silica capillary column at 160°C, split-splitless injector at 180°C, ECD detector at 300°C; Varian, Walnut Creek, CA). TCE concentrations were calculated from a standard curve generated from the analysis of standards prepared and analyzed as described for the samples. Alternately, samples from the columns were analyzed using EPA Method SW48/8260 (purge and trap, GC/MS).

Chloride tracer tests were performed to determine the groundwater flow rate through the columns. Chloride was continuously monitored during tracer tests by replacing the column's top Teflon plug with one holding the combination chloride electrode linked to a strip-chart recorder. Recorder response was calibrated prior to each test by using NaCl standards produced in ground water. After recorder calibration, 10 ml of 4 M NaCl was injected into the bottom of the columns over a one-min. time period and the chloride electrode response was recorded until a distinct chloride peak had passed. Breakthrough curves were analyzed to determine hydraulic conductivity through the columns.

## **2.2 Field Demonstration**

This section presents information on the test site located at the Lakehurst Naval Air Engineering Station. This information includes the current understanding of site geology, hydrogeology, and contaminant distribution at Areas I and J located at NAES. These parameters will be addressed during the implementation of the aerobic biostimulation technology presented in Section 3.0.

## **2.2.1 Site Description**

### **Site Location and History**

The Naval Air Engineering Station (NAES) is located in Lakehurst, New Jersey. NAES encompasses approximately 7,300 acres of land in Jackson and Manchester Townships, Ocean County, New Jersey. In 1987, NAES was designated as a National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). A total of 44 potentially contaminated sites were identified with 42 of the 44 sites included in the Remedial Investigation (RI).

The Eddystone Chemical Company used the area, beginning in 1916, to develop an experimental firing range to test chemical artillery shells. In 1919, the United States Army took control of the site and named it Camp Kendrick. On June 28, 1921, Camp Kendrick was given to the U.S. Navy and the area was commissioned Naval Air Station (NAS). The Naval Air Engineering Center (NAEC) in Philadelphia was moved to NAS in 1974, and the property's name was changed again – this time to NAEC. The base had two more name changes until it's current name was obtained in 1994.

Currently, there are more than 300 buildings in use (with more than 2,845,000 square feet), two 5,000-foot long runways, a 12,000-foot long test runway, one-mile long jet car test track, four one and one-quarter mile long jet car test tracks, a parachute jump circle, a 79-acre golf course, and a 3,500-acre conservation area.

There have been a number of different types of operations and activities performed at the base, which required the use, handling, storage, and on-site storage of hazardous substances. There have been documented, reported, and suspected releases of these substances into the environment.

Areas I and J, the location of this demonstration project, are in the west central portion of the base on the southern boundary (Figure 2.2.1.1). The southern boundary of Area I is on the NAES property boundary. Areas I and J are developed with many buildings including Steam Plant No. 2, the catapult launching facilities and the Runway Arrested Landing Site (RALS) facility. The catapult runway crosses Areas I and J (ROD, 1994). The aerobic biostimulation pilot test study was conducted in the area of Taxiway #4, approximately 300 feet from the southeast property boundary, northwest of Well LK (Figure 2.2.1.2).

The areas surrounding NAES are not heavily developed. The area is mostly residential with some commercial zones. Wildlife management areas lie to the north and south of the base.

## **Geology**

NAES is located in the Outer Coastal Plain physiographic province. This area is characterized by gently rolling hills with minimal relief. Maximum relief in the southwestern part of the site is because the area is near the Inner Coastal Plain. The Inner Coastal Plain has a more rolling terrain than the Outer Coastal Plain. The elevations at NAES range from approximately 60 feet above mean sea level in the eastern portion of the

site to approximately 190 feet above mean sea level in the southwestern portion of the site. Slopes at the site are generally less than 5 percent.

The test area is underlain by approximately 75 feet of unconsolidated sediments characterized as a fairly uniform, brown-yellow, fine to coarse sand (Figure 2.2.1.3). Grain size analyses characterize the sediments as 0.5-5.9% gravel, 85.8-93.6% sand, and 5.1-8.6% clay. Total organic carbon levels ranged from 40 to 800 mg/kg.

## **Hydrogeology**

NAES is part of the Toms River Drainage Basin. This drainage basin is 191 square miles and has a short residence time for surface drainage. The Ridgeway Branch in the north and the Black and Union Branches in the south receive NAES storm drainage waters. There are several headwater streams located on the base property.

NAES has three water bodies within its property. It also has more than 1,300 acres of flood-prone areas (in the south-central area) and approximately 1,300 acres of prime agricultural land (in the western area).

The average depth to groundwater is 7.59 feet. Single well averages ranged from 4.19 feet to 11.89 feet. Groundwater elevations range from approximately 104 feet above mean sea level in the western portion of the study area to approximately 70 feet above mean sea level in the eastern portion of the study area. The average groundwater elevation is 86.54 feet above mean sea level. Single well averages ranged from 80.81 feet to 89.87 feet above mean sea level.

The Cohansey aquifer is assumed to be a single, homogeneous hydrostatic unit. It has an average thickness of 150 feet. Regional groundwater flow in this aquifer is predominantly horizontal. Prior investigations did not find any distinctive confining layers in this aquifer. Groundwater flow in Areas I and J is generally east to southeast towards the property boundary (Figure 2.2.1.4). South of North Ruckles Branch and Black Branch, groundwater flow is to the north, suggesting localized discharge into the streams.

Estimated horizontal hydraulic conductivity values range between 63 feet/day and 99 feet/day. Generally, estimated specific yield values range between 0.057 and 0.23.

The specific capacity of recovery well RW-1 after a 72-hour pump test was estimated at 12.3 gallons per minute per foot of drawdown. The maximum pumping rate for RW-1 during this test was approximately 340 gpm.

### **Contaminant Distribution**

Areas I and J at NAES are under investigation for the remediation of groundwater that was contaminated by various past facility activities and releases. The principle contaminants of concern are chlorinated volatile organic compounds (VOCs) which are found in low concentrations (less than 1ppm) in two discrete areas. One of these areas is east of the catapult area in the vicinity of Well LK and the second is to the south and east of the catapult runway in the vicinity of Well LC (Figure 2.2.1.5). The primary contaminants of

concern include: cis-1,2-dichloroethene, 1,1-dichloroethane, 1,1,1-trichloroethane, trichloroethene, tetrachloroethene, chloroform, and vinyl chloride.

The low-level concentration VOC plumes emanate from several diffuse sources and extend approximately 5000 feet downgradient (Figure 2.2.1.5). Total VOC concentrations in the two plumes are low, generally below 50 µg/L. The most contaminated area is in the vicinity of Well LK, which had a total VOC concentration of approximately 900 µg/L measured in August 1998. Well LK is screened from approximately 55 to 70 feet below ground surface.

Groundwater chemistry near Well LK is characterized by a low pH (~5.2 to 5.5), low alkalinity (6 to 10 mg/L), and low total organic carbon (< 11 mg/L). The groundwater also contains very low or undetectable levels of phosphate, nitrate, nitrite, ammonia, sulfate, and sulfide. The presence of low levels of dissolved oxygen, chlorinated solvent dehalogenation daughter products (c-DCE, and VC), and methane suggest that the aquifer is anaerobic or has anaerobic zones. No ethene, ethane or propane were detected in the groundwater.

## **2.2.2 Well Installation and System Operation**

### **Injection, Recovery, and Monitoring Wells**

The field demonstration system was designed after that of McCarty and co-workers (McCarty et al., 1998). However, whereas that study utilized an *in situ* recirculation system that circulated water between two layers of the aquifer, our system was designed to treat only one layer of aquifer saturated zone with groundwater circulated through a pipe above ground (Figure 1.3.4).

The demonstration system consisted of one test plot (Figure 2.2.2.1) aligned perpendicular to groundwater flow with two injection wells and one recovery well. Also, whereas McCarty and co-workers injected co-substrates (toluene and oxygen) directly into the recirculation stream, a process that resulted in significant plugging problems, we utilized a network of liquid and gaseous substrate injection wells located between the recovery and injection wells. Modflow model simulations were performed with site hydrogeology data and different groundwater pumping rates to determine optimum groundwater capture and well spacing.

Existing well RW-1 was used for groundwater recovery. Two groundwater injection wells IW-1 and IW-2 were installed and screened over the same interval as RW-1 (40 to 65 ft bgs). Nine liquid substrate injection wells were installed and screened from 40 to 65 ft bgs. Ten gaseous substrate injection wells were installed and screened from 40 to 65 ft bgs. Seven monitoring wells were installed and screened from 40 to 65 ft bgs. Three soil vapor monitoring probes were installed to a depth of 6 ft. and screened from 5 to 6 feet.

### **Drilling Methods and Sediment Sampling**

Injection, monitoring, gas injection, and liquid injection wells were installed using HSA (Summit Drilling of Bound Brook, New Jersey). Sediment samples were collected during soil boring by standard split spoon methods. Sediment was logged during the boring activities according to grain size and color. Samples were taken for particle size analysis and VOC analysis.



## **Well Construction**

Groundwater injection wells were installed to a depth of 65 feet and constructed of 4" PVC casing and 20 feet of 0.020" screen slot placed from 45 to 65 feet below ground surface. Nine small diameter liquid substrate injection wells were installed and constructed with 20-foot screens from 45 to 65 ft bgs (Figures 1.3.4 and 1.3.5). Ten gaseous substrate (propane) and oxygen injection wells were installed and constructed with 20-foot screens over the interval from 45 to 65 ft bgs.

Groundwater monitoring wells were installed to a depth of 65 feet and constructed of 2" PVC casing and 20 feet of 0.020" screen slot placed from 45 to 65 feet below ground surface. Soil vapor monitoring probes were installed to a depth of 6 feet and constructed of 1" PVC casing and 1 foot of 0.020" screen slot from 5 to 6 feet below ground surface. An example of a finished well is shown in Figure 2.2.2.2.

## **Groundwater Recovery & Injection System**

The pilot test system consisted of a groundwater recirculation system aligned perpendicular to groundwater flow and a network of liquid and gaseous substrate injection wells (see above).

Figure 2.2.2.1 provides a plan view of the test plot layout showing the spatial distribution of extraction and injection wells, and Figure 2.2.2.3 shows a photo of the above ground system.

Figure 1.3.4 provides a cross-section view of a simplified test plot schematic that depicts each of the various types of injection wells. Existing well RW-1 was used for groundwater recovery.

Two groundwater injection wells were installed and screened over the same interval as RW-1 (40 to 65 ft bgs) at the other end of the treatment zone to create a groundwater capture zone perpendicular to groundwater flow. Liquid substrate injection wells and gaseous substrate wells

were installed within the capture zone to distribute oxygen, propane and nutrients into the groundwater.

### **Gaseous and Oxygen Delivery System**

Ten gaseous substrate (propane) and oxygen injection wells were also installed and were constructed with 20-foot screens over the interval from 45 to 65 ft bgs. Each of the gaseous injection wells was equipped with a silicone diffuser tube that distributed propane and oxygen over the entire screened interval (see Detail A on Figure 1.3.5). Propane and oxygen injection lines were protected within 2" PVC pipe (Figure 2.2.2.2).

### **Nutrient Injection System**

The nutrient injection system consisted of a nutrient drum and mixer with a calibration column and metering pump (Figure 2.2.2.2). Nutrients were injected via a metering pump system into the equalization tank, which was then pumped into the system for injection into IW1 and IW2. A separate liquid injection system was constructed for adding liquid cosubstrates such as propanol and butanol (Figure 2.2.2.2).

### **Pilot System Operation**

The pilot system was operated from September 13, 1999 to July 10, 2000. Pilot system operations consisted of groundwater recirculation creating a capture zone, with periods of oxygen supplementation, propane addition, and nutrient addition. Monitoring was conducted for recovery well and injection flow rates, supplied oxygen flow rates, supplied propane flow rates, and nutrient addition rates.

### **2.2.3 Hydraulic Evaluation**

After installation and well development, slug tests were performed in each of the injection wells, the recovery well, the monitoring wells, and two liquid injection wells. Slug test data was analyzed to determine the aquifer hydraulic conductivity in the test plot area. Analysis of the slug test data from thirteen wells indicated that the aquifer has an average hydraulic conductivity of 0.03215 cm/sec and an average transmissivity of 0.01470 m<sup>2</sup>/sec. These values for hydraulic conductivity and transmissivity correspond to values of a well sorted sand.

### **2.2.4 Sampling and Analyses**

#### **Groundwater Sampling and Analysis**

Groundwater sampling protocols are detailed below, and analytical methods are listed in Table 2.2.4.1.

#### **Sampling Procedure and Equipment**

Well purging and sampling were performed in accordance with the USEPA SOP for low-flow (minimum stress) purging and sampling (Appendix A). The general sequence and procedures for monitoring well purging and sampling were as follows:

1. Depth to water was measured prior to purging wells by using a Solinst water level measurement probe marked to the nearest 1/100 foot.
2. Prior to collecting groundwater samples, monitoring wells were purged in accordance with the USEPA Low-Flow (minimum stress) Purging and Sampling procedure. Purging was accomplished using dedicated QED Model P1101M bladder pumps installed in each monitoring well.

3. The pH, ORP, DO, specific conductivity, and temperature of the groundwater were measured continuously with a Horiba U-22 and flow-through cell during purging until the parameters had stabilized. All field meters were calibrated daily prior to use in accordance with manufacturer's specifications.
4. After purging and recording field monitoring parameters, groundwater samples were collected in accordance with the USEPA Low-Flow Purging and Sampling procedure using a dedicated QED bladder pump. Groundwater samples collected for dissolved metal analyses were field filtered using in line 0.45 micron filter.
5. Chain-of-custody records were completed and enclosed in the shipping coolers with the appropriate samples. These documented or denoted any transfer of custody and method of shipment.
6. Samples were maintained at a temperature of 4°C or less and were hand delivered by field personnel to the laboratory within 24 hours after collection

### **Analytical Methods**

Collected groundwater samples were delivered to Envirogen, Inc. and analyzed using standard EPA-approved methods. Quality assurance samples including trip blanks, field blanks, and field duplicates were collected periodically. Water samples were analyzed for VOCs, limited chemistry parameters, metals, and biological parameters. Analytical methods, bottle types, and preservatives used for each analysis are listed in Table 2.2.4.1.

### 3. RESULTS AND DISCUSSION

#### 3.1 Laboratory Studies

**Enrichment Culturing.** Enrichment culturing was performed to determine if VOC-degrading bacteria capable of growth on biostimulation substrates reside in the Lakehurst aquifer.

Enrichments were performed by adding aquifer samples to BSM media with the biostimulation substrate as the sole carbon source. Substrates included 1-butanol, butane, 2-propanol, and propane. Cell growth was observed in cultures containing 1-butanol and 2-propanol, but not in cultures fed propane or butane. None of the butanol-grown nor propanol-grown enrichment cultures, however, were able to degrade TCE in standard bottle assays.

**Microcosms.** Microcosms studies were performed to evaluate whether the addition of propane or 2-propanol would stimulate *in situ* degradation of VOCs, to evaluate VOC degradation rates, to evaluate substrate utilization and oxygen demand, and to assess the need to add supplemental nutrients to support degradation. Microcosms were constructed with aquifer solids and groundwater from the Lakehurst site and incubated at *in situ* temperatures for more than 250 days. Manipulations and sampling of the microcosms are detailed in Table 3.1.1.

Microcosms fed with 2-propanol degraded the added 2-propanol slowly over the 250 day incubation (Figure 3.1.1). In the presence of added nutrients, however, 2-propanol was completely degraded during the first 10 days of incubation, and additional spikes of 2-propanol were rapidly metabolized in the microcosms. Propane was not degraded in microcosms with or

without the addition of nutrients (Figure 3.1.2). Likewise, the addition of 2-propanol to propane-fed microcosms did not stimulate propane degradation.

No TCE degradation was observed in any of the aquifer microcosms (Figure 3.1.3), and the addition of nutrients did not enhance degradation.

**Column Studies.** In addition to microcosm and enrichment culture studies, laboratory column studies also were performed to evaluate *in situ* VOC degradation. Column studies have an advantage over microcosm studies because they allow continuous feeding and monitoring of co-metabolic substrate, oxygen and pH. Furthermore, the amount of target substrate added to the samples can be adjusted by altering its concentration in the feed water, or by altering feed flow rates. The columns also allowed the passing of large volumes of groundwater through the aquifer solids, thereby increasing the probability of seeding the columns with propanotrophs that could be present at very low concentrations in the groundwater. Manipulations and sampling of the columns are detailed in Table 3.1.2.

Oxygen and propane were added to the columns by developing a membrane diffusion apparatus constructed with silicone tubing plugged on one end. The plugged tubing was inserted into the groundwater reservoir and propane or oxygen was added to the tubing to a final pressure of 7.5 psi. Propane and oxygen then diffused through the silicone tubing and dissolved in the groundwater held in the reservoir. During experiments designed to evaluate and calibrate the gas diffusion system resulted in dissolved propane concentrations of nearly 3 mg/L and dissolved oxygen concentrations of approximately 17 mg/L after 24 hrs (Figure 3.1.4).

Dissolved oxygen concentrations entering the columns were maintained at approximately 14 mg/L during the first 70 days of operation (Figure 3.1.5), and they were increased to 25 mg/L by doubling the amount of tubing on the diffusion system. During the initial 20 days of operation, effluent oxygen concentrations were between 15 and 7 mg/L, and they declined to approximately 3 mg/L after the groundwater flowrate to the columns was reduced (see below). Dissolved oxygen concentrations in the effluent increased to approximately 15 mg/L between days 70 and 80 after propane addition was terminated and the diffusion membrane area was doubled. Dissolved oxygen concentrations were measured only sparingly during the remainder of the study (days 80 to 250), and they remained above 5 mg/L.

Groundwater flow into the columns was maintained by using a peristaltic pump (Figure 3.1.6). Initially, groundwater was added at a high rate (40 ml/min) to load the columns with TCE. Groundwater flow was then reduced to 20 ml/min and maintained at 20 ml/min during days 10 through 80. On day 80, groundwater flow rate was reduced to approximately 5 ml/min to increase the hydraulic residence time in the columns, and maintained at this flow rate for the remainder of the study.

The effect of groundwater pH on VOC degradation was evaluated by operating columns 1 and 2 at a pH of approximately 7, while columns 3 and 4 were operated at the ambient pH of between 5 and 5.5 (Figure 3.1.7). The chosen pH of the influent groundwater remained relatively stable throughout the study, and the pH of the effluent groundwater was similar to that of the influent groundwater.

Propane concentrations in the influent groundwater was maintained at approximately 3 mg/L during the first 20 days of operation, and it was then increased to approximately 6 mg/L in an attempt to enhance growth of propanotrophs in the columns (Figure 3.1.8). On day 70, propane feed concentrations were reduced to < 1 mg/L to prevent competitive inhibition that may have occurred because of excess propane loading. In each column, effluent propane concentrations were similar to influent concentrations, suggesting that propanotrophs were not active in the columns.

TCE was added to the columns at a concentration from between 0.2 and 2 mg/L. In both the pH adjusted and non-adjusted columns effluent TCE concentrations were similar to influent concentrations, thereby indicating that TCE was not being significantly degraded in the columns (Figure 3.1.9). Increasing the groundwater residence time in the column did not improve TCE degradation.

**Effect of seeding on TCE degradation.** To evaluate whether seeding of the aquifer would improve *in situ* VOC degradation, the TCE-degrading propanotroph bacterium strain ENV425 was added to the column 1 (pH adjusted), and the influent and effluent TCE concentrations were monitored for 8 days (Figure 3.1.10). Although effluent TCE concentrations were slightly lower than influent concentrations, effluent TCE concentrations were not reduced to below 0.5 mg/L. Furthermore, effluent concentrations closely paralleled influent concentrations, suggesting that TCE degradation in the columns was minimal.



In a second seeding experiment, column 1 was seeded with the TCE-degrading toluene oxidizing bacterium *Burkholderia sp.* ENV735. This strain has been used extensively in our laboratory and has been successfully deployed in a field demonstration funded by another DoD SBIR contract (Steffan et al., 1999). The addition of ENV735 at a concentration of  $1 \times 10^9$  cells/gm soil to column 1 resulted in rapid TCE degradation (Figure 3.1.11). Influent TCE concentration was approximately 4 mg/L, and effluent concentrations in the augmented column were reduced to < 1 mg/L within 24 hr., and ~ 0.1 mg/L in 43 hr. By contrast, effluent concentrations in the non-augmented control column were approximately 3 mg/L during the entire 43 hr. incubation. In both columns the effluent TCE concentration increased after 48 hr. of incubation. The hydraulic residence time within the columns was 4 hr., indicating that more than 10 column volumes of groundwater were treated by the added organisms.

## **3.2 Field Demonstration**

For field-scale implementation, propane was added to generate a population of TCE-degrading bacteria and to maintain a constant level of degradative activity. When applied in a recirculating groundwater system as used by McCarty and co-workers at Edwards AFBCA (McCarty, et al., 1998), the system can create an *in situ* treatment zone (biocell) which would require a minimum of maintenance and oversight.

### **3.2.1 Biomass**

Biomass was sampled throughout the pilot test to quantify possible effects of variables on heterotroph populations. The total heterotrophs and specific heterotrophs (propanotrophs) were analyzed from August 1999 to July 2000 on a monthly to bimonthly basis (see attached data tables). Highest levels of heterotrophs occurred in August 1999 sampling and did not increase

through operation of system with most wells having values less than the detection limit (<300 cfu/ml) or estimated values. Propanotroph populations were below detection throughout the study. The reason for the low microbial populations was likely due to the low pH of the aquifer, or the lack of labile organic matter in the aquifer prior to propane injection.

### **3.2.2 Oxygen Use and Distribution**

Oxygen was used to develop aerobic conditions conducive to increasing microbial populations and the aerobic degradation of VOCs. Ten gaseous injection well points were used to distribute oxygen beginning on October 28, 1999 (Figure 2.2.2.1). The oxygen was injected through the membrane diffusers at a continuous rate of approximately 0.20 lbs/day. Distribution of oxygen was delineated via monthly to bi-monthly sampling of various test plot wells using a Horiba U-22 meter and probe and a flow through cell (Figures 3.2.2.1 to 3.2.2.13). Oxygen was detected in all of the wells at various levels during the demonstration. The maximum oxygen concentration was detected in well OW-5 (7.38 mg/L), but oxygen was not uniformly distributed in the test plot. Some oxygen consumption was likely facilitated by the abiotic oxidation of ferrous iron ( $\text{Fe}^{2+}$ ) in the aquifer.

Monitoring wells outside of the treatment zone included MW-1 and MW-7. Dissolved oxygen levels in these wells varied throughout the demonstration with an increase in concentrations occurring after oxygen injection began in late October. Highest oxygen levels in these wells were measured late December (Figures 3.2.2.1 and 3.2.2.7).

Monitoring wells inside of the treatment zone included OW-1, OW-5, MW-2, MW-3, and MW-4. Dissolved oxygen levels for these wells varied throughout the demonstration with a measured

increase in concentration after oxygen injection began in late October (Figures 3.2.2.2, 3.2.2.5, 3.2.2.11, 3.2.2.12). Oxygen levels in MW-2, MW-3, and MW-4 were fairly consistent throughout the oxygenation period. OW-1, on the periphery up gradient slightly for the treatment zone, experienced a persistence of low dissolved concentrations throughout the demonstration. OW-5 was a shallower monitoring point (30 ft bgs), above the level of oxygen injection, and it showed a decrease in dissolved oxygen levels during oxygen injection. The decrease in dissolved oxygen levels for OW-5 is probably due to seasonal influences.

Monitoring wells down gradient of the treatment zone included MW-5, MW-6, MW-8, OW-6, and Well LK. Each of the down gradient monitoring wells exhibited an increase in dissolved oxygen levels when oxygen injection began in late October (Figures 3.2.2.5, 3.2.2.6, 3.2.2.8, 3.2.2.9, 3.2.2.13).

### **3.2.3 Co-Substrate Use and Distribution**

Propane was used as a co-substrate to maintain and increase the microbial population beginning on January 12, 2000. Addition of propane was achieved via gaseous injection into 10 wells within the capture zone (Figures 3.2.2.1 to 3.2.2.13). The propane was injected at a rate of approximately 2.7 lbs/day. Propane distribution was sampled at least biweekly for wells OW-5, MW-3, MW-4, MW-5, MW-8, and RW-1, and monthly for the other wells (Appendix B).

Propane was detected in each of the test plot monitoring wells during the demonstration. The highest level of propane was detected in MW-4 (2.96 mg/l), but there was no discernable overall trend in propane concentration among the wells during the study.

Monitoring wells outside of the treatment zone included MW-1 and MW-7. Propane was detected in MW-7 which was close the treatment zone, but not in the more distant MW-1. MW-7 propane levels varied markedly during the study period.

Propane was detected in all of the treatment zone wells (OW-1, OW-5, MW-2, MW-3, and MW-4) once propane injection began on January 12, 2000 throughout the trail. Propane levels, however, were not consistent during the trail from sample to sample, presumably due to pressure swings caused by propane cylinders being expended and not changed immediately, and a diffuser tube breakage that was not repaired immediately.

Monitoring wells down gradient of the treatment zone (MW-5, MW-6, MW-8, OW-6, and Well LK) also had measurable dissolved propane, with the greatest levels occurring during February and March.

### **3.2.4 Nutrient Use and Distribution**

Nutrient supplementation began on March 23, 2000 to increase and stimulate the microbe population within the test plot. The nutrient solution was 50 pounds All-Purpose 10-10-10 fertilizer, consisting of (w/w)10% Nitrogen compounds, 10%  $P_2O_5$ , 10%  $K_2O$ , in water (39.63 gallons) from RW1 in the nutrient holding tank. A metering pump was set to inject the solution (at a nutrient concentration of 150 g/L) into the recirculation equilibration tank at a rate of 0.0033 gallons per minute. The recirculation equilibration tank, which on average held 375 gallons, was injecting at a rate of approximately 20 gallons per minute. A total of  $1.76 \times 10^{-4}$  gallons per minute of nutrient supplementation was injected into the groundwater system. This

rate of injection did not impact groundwater nitrite, nitrate, and phosphate levels in wells outside of the treatment zone.

### **3.2.5 Geochemistry**

The geochemical environment of the test plot was moderately anaerobic, characterized by low dissolved oxygen concentrations and reducing conditions (low reduction-oxidation potential).

Field parameters measured in the Test plot during the study are summarized in Appendix B. The average dissolved oxygen concentration in the demonstration area was 0.526 mg/l and dissolved oxygen in individual test plot monitoring wells reached approximately 1 mg/L. The average pH in the demonstration area was 5.0 with a range of 4.2 to 5.8. The average ORP was 177 mv in treatment zone and surrounding monitoring wells, with a range of -54 to 379 mv.

### **3.2.6 VOC Degradation**

The volatile organic compounds of interest in the aquifer were TCE, PCE, and cis-DCE.

Samples from each test plot well were analyzed for all VOCs. TCE, PCE, and cis-DCE concentrations through time for each well are shown in Figures 3.2.6.1 to 3.2.6.13. Though a decrease in TCE, and cis-DCE concentrations was observed in some wells, the PCE concentrations also decreased. Because PCE is not biologically degraded under aerobic conditions, it was used as an internal standard to normalize VOC concentrations. Results of the data normalization indicated that VOCs were not significantly degraded in the aquifer (Figures 3.2.6.14 through 3.2.6.21). Monitoring wells outside of the treatment zone (MW-1 and MW-7) showed only seasonal variations (MW-1) or no change (MW-7) in VOC concentrations during

the study. The down gradient wells (MW-5, MW-6, MW-8, OW-6, and Well LK) had no apparent degradation of VOCs.

#### **4. CONCLUSIONS**

Results of this study demonstrate that the recirculating groundwater capture system coupled with *in situ* diffusive membranes provides a suitable method for introducing gaseous substrates to the subsurface and creating an *in situ* biotreatment zone. The results also demonstrate that some aquifers may be devoid of suitable co-metabolic VOC-degrading bacteria populations, and that the introduction of propane and oxygen to these aquifers may not stimulate *in situ* VOC degradation within a suitable time frame to facilitate timely remediation of the sites. Up-front laboratory treatability testing is required to determine the utility of *in situ* biostimulation at selected sites, and in some cases seed cultures will be needed to support *in situ* co-metabolic VOC degradation. The results of the field demonstration also show that the approach used during this project can provide a cost-effective treatment alternative when applied at a suitable site. Co-substrate costs are low, and the recirculation system allows treatment of a relatively large portion of a contaminated aquifer with the installation of only a few wells. The amount of wells required can be further reduced by using alternative co-substrate injection systems (e.g., push probe-installed sparging points that have a greater radius of influence) where concerns about fugitive releases of co-substrates are not great.

## **5. RECOMMENDATIONS**

Based on the results of this study, it is clear that propane biostimulation is not suitable for *in situ* VOC degradation at all VOC-contaminated sites. However, it is recommended that the utility of this technology be further evaluated and considered because of its relatively low cost and ease of application. Furthermore, it is recommended that up-front treatability testing be performed at all sites prior to application, and that the use of bacterial seeding prior to substrate injection be evaluated as a modification of the technology for sites without an adequate resident VOC-degrading microbial population.

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## TABLES

**TABLE 2.2.4.1**

**ANALYTICAL METHODS**

<b>Matrix</b>	<b>Analyte Type</b>	<b>Method Name</b>	<b>Container Type</b>	<b>Container Size</b>	<b>Preservative</b>	<b>Holding Time</b>
Water	VOCs	8260B	glass	40 ml (3)	HCL, cool (4°C)	7 days
	Total Heterotrophs	9215 C SM	plastic	50 ml	None	24 hours
	Substrate Specific Heterotrophs	9215 C SM Modified	plastic	50 ml	None	24 hours
	ALCOHOLS 1-butanol 1-propanol 2-propanol	8015B	glass	40 ml	None	14 days
	DISSOLVED GASES Propane Carbon Dioxide	8015B	glass	40 ml	None	14 days
	Iron, total	7380	glass	250 ml	Nitric Acid	6 months
	Iron, dissolved	7380	glass	40 ml	Nitric Acid, filtered	6 months
	Total Organic Carbon	415.1	glass	40 ml	H <sub>2</sub> SO <sub>4</sub> , cool (4°C)	28 days
	Anions (SO <sub>4</sub> <sup>-</sup> , Br <sup>-</sup> , Cl <sup>-</sup> )	300	glass	40 ml	cool (4°C)	48 hours
	Phosphate (Total)	365.2	glass	250 ml	None	2 days
	Alkalinity	310.1	glass	120 ml	None	14 days
	Ammonia Nitrogen	350.2	glass	250 ml	H <sub>2</sub> SO <sub>4</sub>	28 days
Soil	VOCs	8260B	glass	40 ml (3)	Methanol, cool (4°C)	7 days
	Porosity	ASTM D6412	brass	6" sleeve	None	NA
	Particle Size Distribution	ASTM D422	brass	6" sleeve	None	NA
	Total Organic Carbon	415.1	glass	40 ml	cool (4°C)	28 days
Vapor	Propane	8015B	Tedlar bag	2-liter	None	7 days

**Table 3.1.1. Lakehurst Microcosm Study History.**

**7/13/99(T=0)** Set up microcosms (15 °C shaken on side).  
-Wet soil (GW5 composite 45-65' depth) wt. = 50 gr/bottle  
-Ground water = 55 ml (assume total with soil water to be 60 mL)  
NA (1, 2, 3)= no amendments  
Kill (1, 2, 3)= no amendments + 1 mL [7.4%] HgCl<sub>2</sub>, 1 mL [15%] sodium azide  
Pol (1, 2, 3)= 50 ppm propanol  
Pol+K-G (1, 2, 3)= 50 ppm propanol + [1X] K-grow  
Pane (1, 2, 3)= 2 mg propane  
Pane+K-G (1, 2, 3)= 2 mg propane + [1X] K-grow  
**7/14/99(T=1)** Tested [TCE] and it was very low.  
Spiked microcosms to 2 ppm TCE.  
-CFU/mL:  
R2A =  $7.0 \times 10^5$  (+/-  $4.4 \times 10^4$ ) counted 7/20/99  
BSM + Propane =  $5.2 \times 10^5$  (+/-  $5.5 \times 10^4$ ) counted 8/5/99  
BSM + Propanol =  $1.2 \times 10^5$  (+/-  $2.5 \times 10^4$ ) counted 7/20/99  
Analyzed for propane, TCE, and propanol.  
**7/19/99(T=6)** Analyzed for propane, TCE, and propanol.  
**7/26/99(T=13)** Analyzed for propane, TCE, and propanol.  
**7/29/99(T=16)** Analyzed Pol+K-G for propanol and none found,  
spiked bottles with 38 uL of 10% propanol.  
**8/2/99(T=20)** Analyzed for propane, TCE, and propanol.  
T=20.1 days: Spiked Pol+K-G bottles with 38 uL of 10% propanol.  
**8/9/99(T=27)** Analyzed for propane, TCE, and propanol.  
T=27 days: Spiked Pol+K-G bottles with 1 mL of propane.  
**8/16/99(T=34)** Analyzed for propane, TCE, and propanol.  
**8/25/99(T=43)** Analyzed for propane, TCE, and propanol.  
Added 5 mL O<sub>2</sub> to bottles, sat 2 hours before re-capping.  
**9/1/99(T=51)** Analyzed for propane, TCE, and propanol.  
**9/8/99(T=58)** Analyzed for propane, TCE, and propanol.  
**9/30/99(T=80)** Analyzed for propane, TCE, and propanol.  
**10/27/99(T=107)** Analyzed for propane, TCE, and propanol.  
**11/29/99(T=140)** Analyzed for propane, TCE, and propanol.  
**01/05/00(T=198)** Analyzed for propane, TCE, and propanol.  
**03/16/00(T=269)** Analyzed for propane, TCE, and propanol.

**Table 3.1.2. Lakehurst Column Study History.**

**7/21/99** Set-up four columns (and one extra=EX)

All soil composite, screened, moist, and packed under ground water.

Soil: C1= 2109 g	Ground water: C1= 40 ml
C2= 2077 g	C2= 65 ml
C3= 2074 g <u>mean = 2080 g</u>	C3= 55 ml <u>mean = 54 ml</u>
C4= 2061 g	C4= 55 ml
EX= 2406 g	EX= 70 ml

200 g wet soil → dry= 166.8 g, therefore 0.17 mL H<sub>2</sub>O/g wet soil:  
 (0.17 mL H<sub>2</sub>O/g wet soil)(2080 g wet soil/column)+54 mL H<sub>2</sub>O= **407.6 mL**

**H<sub>2</sub>O/column.**

**7/23/99** Started contaminate into columns:

240 ppm (16 uL neat TCE/100 ml ddH<sub>2</sub>O) @ 0.125 ml/hour.

**7/28/99** Increased contaminate flow rate to 0.150 ml/hour.

**8/2/99** Increased contaminate stock concentration to 293 ppm (20 uL neat TCE/100 ml ddH<sub>2</sub>O). Started adding K-Grow to ground water at 0.1x final concentration.

**8/10/99** Increased propane PSI to 7.5.

**8/11/99** Plated no amendments and propane+K-grow samples on BSM + propane.

**8/12/99** Refer system ran low on coolant, column temp= 21 °C. Refilled system and temp= 15 °C.

**8/13/99** Refer pump stopped working, replaced with external pump (GC/Winkler done at 21 °C).

Performed Winkler titration on columns and reservoir.

Column temperature = 12 °C

**9/1/99**(day 40) Column temp. still between 11-13 °C.

**9/3/99**(day 42) Refilled contaminate syringes with 293 ppm TCE and reset rate to 0.10 ml/hr.

Column temp. still between 11-13 °C.

**9/30/99**(day 70) Shut off propane to reservoir after sampling for TCE, propane, O<sub>2</sub>.

**10/7/99**(day 77) Emptied reservoir and cleaned, attached propane tube to O<sub>2</sub>,

**10/13/99**(day 83) Cut flow rate to columns

**10/18/99**(day 89) Cut TCE feed concentration in half.

**10/25/99**(day 89) Turned propane on to first reservoir (propane+O<sub>2</sub>):

Constructed 2<sup>nd</sup> reservoir for O<sub>2</sub> only.

**10/27/99**(day 98) Buffering columns 1 and 2 with [5x] phosphate buffer in contaminate syringes:

- 1) mix 10 uL neat TCE in 100 mL ddH<sub>2</sub>O
- 2) Dilute 1:1 in ddH<sub>2</sub>O or [10x] phosphate buffer
- 3) Place into syringes

**11/1/99**(day 103) Doubled TCE concentration (see above=20 uL neat TCE).

4:00 PM switched to O<sub>2</sub> only reservoir for columns.

**11/5/99**(day 107) 9:00 AM switched to O<sub>2</sub>+propane reservoir.

Added stop cocks to influent lines.

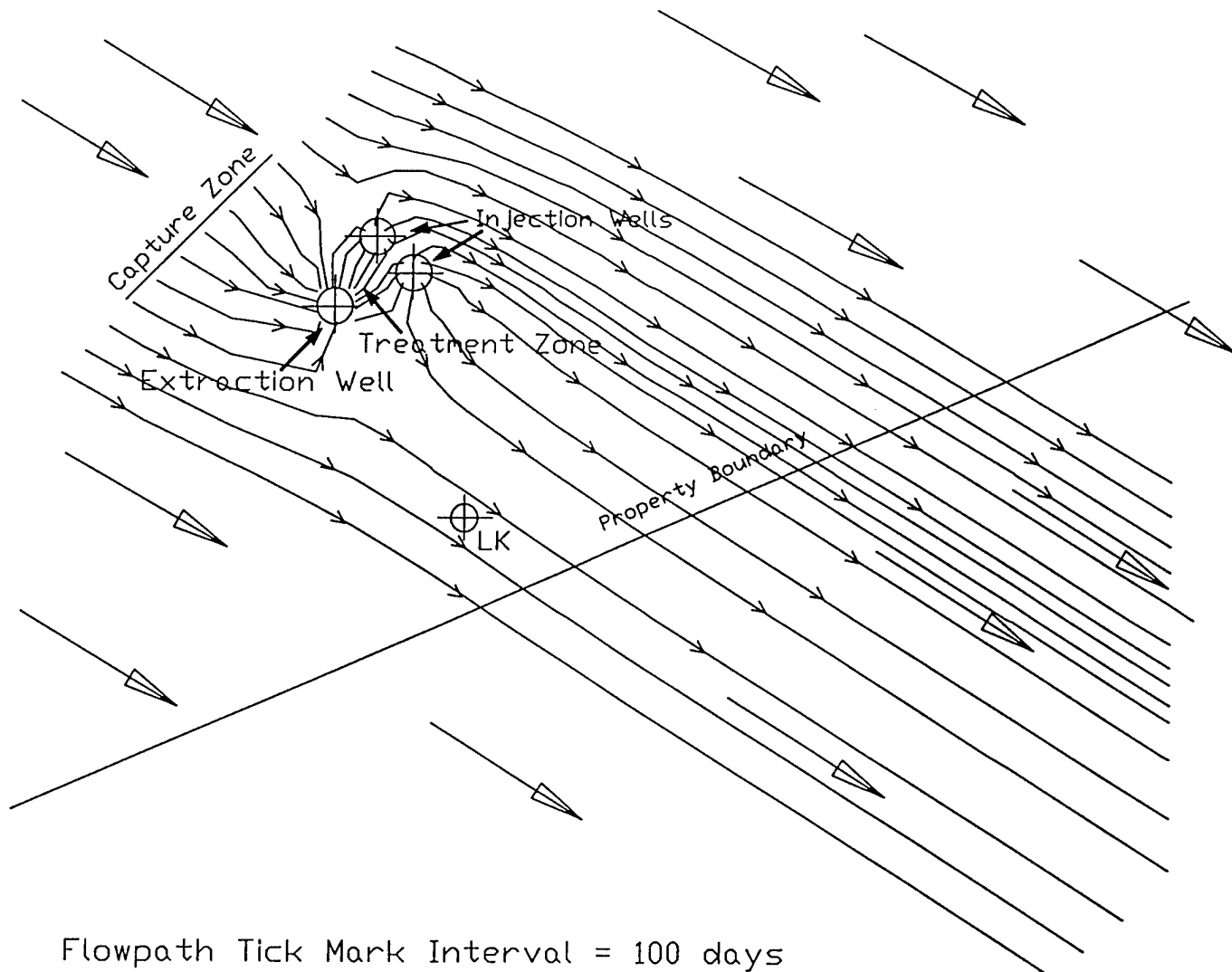
**11/8/99**(day 110) 4:30 PM switched to O<sub>2</sub> only reservoir.

11/12/99(day 114) Noon switched to O<sub>2</sub>+propane reservoir.  
 11/15/99(day 117) 9:00 switched to O<sub>2</sub> only reservoir.  
 11/19/99(day 121) 8:00 switched to O<sub>2</sub>+propane reservoir.  
 11/24/99(day 126) 10:30 switched to O<sub>2</sub> only reservoir.  
 11/29/99 (day 131) 10:30 switched to O<sub>2</sub>+propane reservoir.  
 12/3/99(day 135) Discovered that Column 1 syringe leaked and ruined the pump. Also, no GW flow through column 1. Switched pumps. 7:30 switched to O<sub>2</sub> only reservoir.  
 12/6/99(day 138) 9:00 switched to O<sub>2</sub> + propane reservoir.  
 12/10/99(day 142) 1:00 switched to O<sub>2</sub> only reservoir.  
 12/14/99(day 146) 1:00 switched to O<sub>2</sub> + propane reservoir.  
 12/15/99(day 147) 9:00 switched to O<sub>2</sub> only reservoir.  
 12/20/99(day 152) 8:30 switched to O<sub>2</sub> + propane reservoir.  
 12/23/99(day 155) Shut off contaminate feed to columns and put in a recirculation mode (vacation) with columns 1 and 2 sharing one reservoir and columns 3 and 4 sharing the other (so as not to buffer columns 3 and 4)  
 1/3/00(day 165) Cleaned out both reservoirs and lines to columns and reset configuration as normal. Both columns receiving O<sub>2</sub> + propane and TCE.  
 3/21/00(day 243) 2:30 switched to O<sub>2</sub> only reservoir.  
 3/27/00(day 249) 10:30 switched to O<sub>2</sub> + propane reservoir.  
 3/28/00(day 250) Shut down the contaminate feed as leaking is getting worst  
 3/30/00(day 258) Got new 10 mL gastight syringes in, so I started metering in the 293 ppm TCE and PO<sub>4</sub> buffer (columns 1 and 2).  
 4/7/00(day 266) Quit using phosphate buffer in columns 1 and 2 as the syringes are starting to leak again. Loaded the contaminate syringes with 174 ppm TCE (10 uL neat TCE/100 mL ddH<sub>2</sub>O). Switched flow to O<sub>2</sub> only.  
 4/24/00 (day 283) Injected 100 mL of TCE active ENV425 into columns 1 & 3 followed by 20 mL GW. Injected 120 mL of GW into columns 2 & 4.  
 4/28/00 (day 287) Switched to propane + O<sub>2</sub> GW for the weekend.  
 5/2/00 (day 291) Switched to O<sub>2</sub> only GW.  
 5/22/00 (day 311) Adding 10x Phosphate buffer to the GW reservoir (10 mL/L = pH 7.0). Started running in batch mode at ~100 mL/hour.  
 5/23/00 (day 312) Increased contaminate flow rate ten fold to 1.0 mL/hour.  
 5/31/00 (day 320) Ran batch mode (100 mL/hour) for 5 hours, then inoculated Columns 1 & 2 with 20 mL of PR1A-strep 4 and Columns 3 & 4 with BSM; sampled T=0 effluent. Ran for one more hour; sampled T=0 influent, then shut down overnight.  
 6/1/00 (day 321) Ran batch mode (100 mL/hour) for 5 hours. Sampled effluent @ 20 min and influent at the end of the day (just after last effluent sample). Shut down overnight.  
 6/2/00 (day 322) Ran batch mode (100 mL/hour) for 6 hours. Sampled effluent @ hour and influent at the end of the day (just after last effluent sample). Shut down over the weekend.

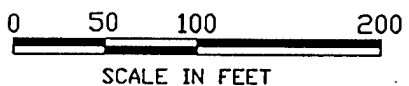


## FIGURES

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Flowpath Tick Mark Interval = 100 days



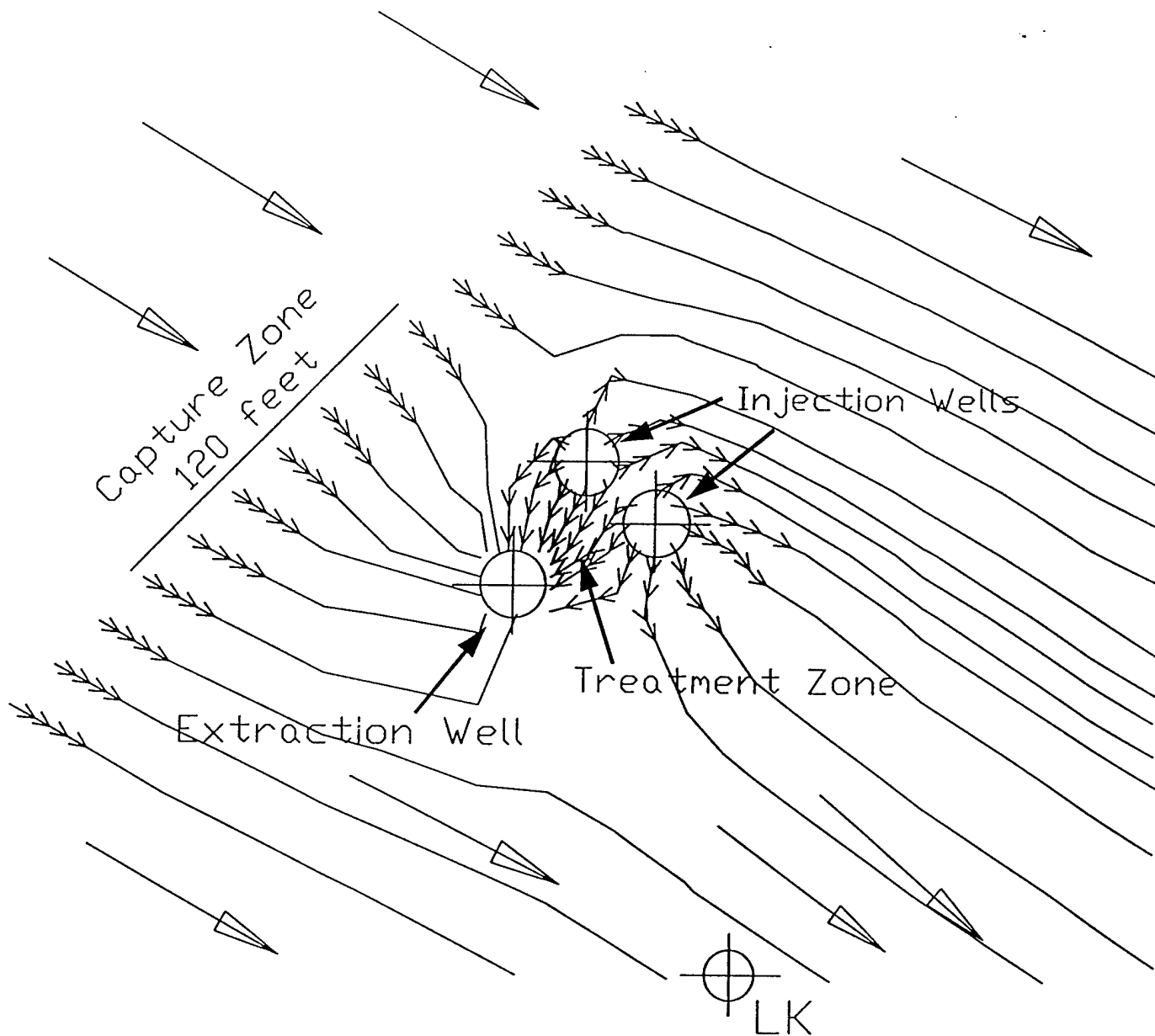
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Figure 1.3.1					SHEET SIZE
					A
Naval Air Engineering Station					REVISION
Lakehurst, New Jersey					SHEET 1 OF 1
1 Flow Field - 25 gpm					DRAWING #
					Figure 1.3.1
					FILE # Figure1-3-1.dwg



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SCALE IN FEET

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Figure 1.3.2						
Naval Air Engineering Station Lakehurst, New Jersey Flow Field - 25 gpm						
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SHEET 1						OF 1
DRAWING #						Figure 1.3.2
FILE #						Figure1-3-2

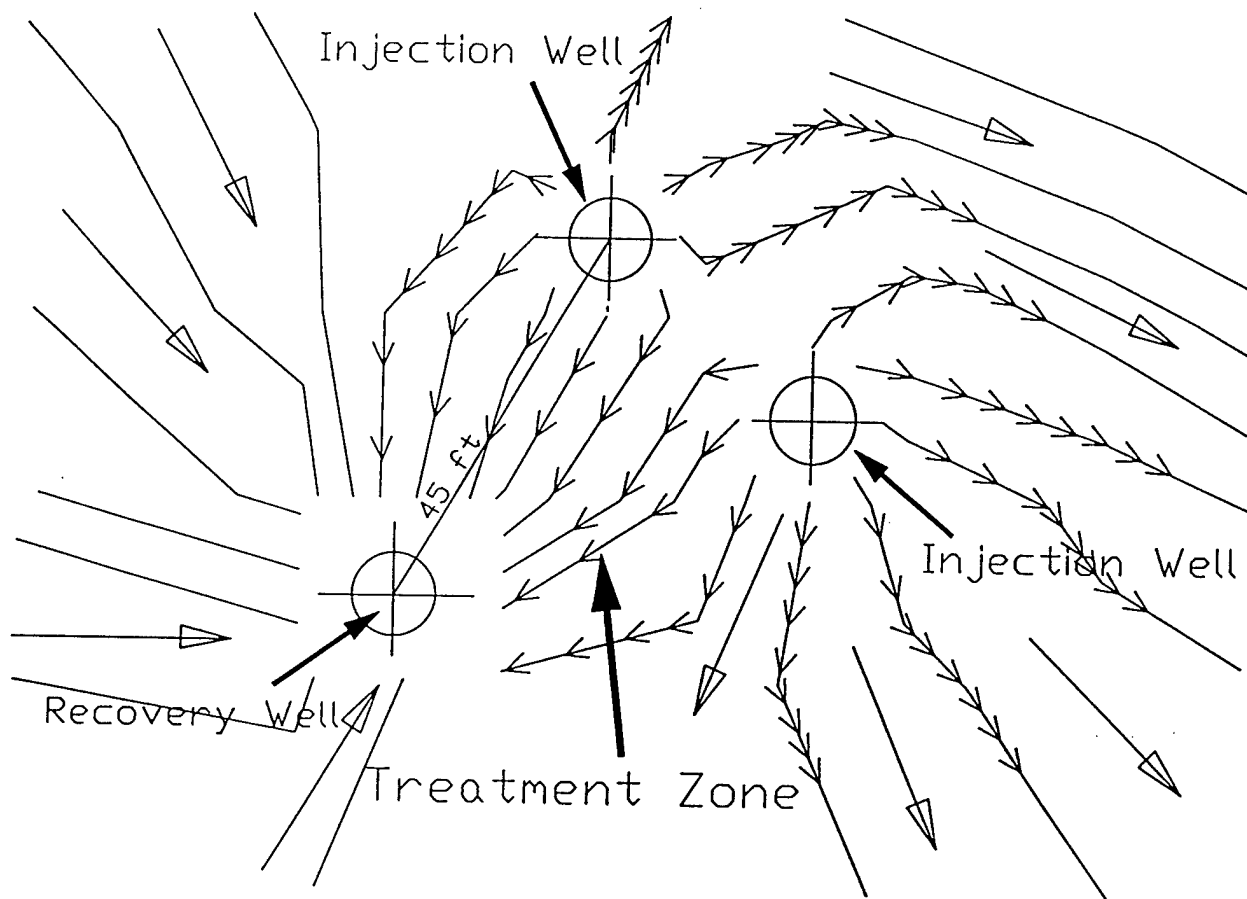


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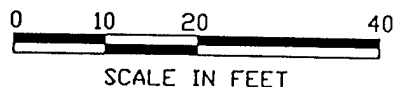
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Naval Air Engineering Station  
Lakewood, New Jersey  
Flow Field - 25 gpm

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Travel Time - 6 to 16 days  
Tick marks on flow paths are 2-day intervals



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					Figure 1.3.3
					FILE #
					Figure 1.3.3



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**Figure 1.3.3**  
Naval Air Engineering Station  
3 Lakehurst, New Jersey  
Treatment Zone - 25 gpm

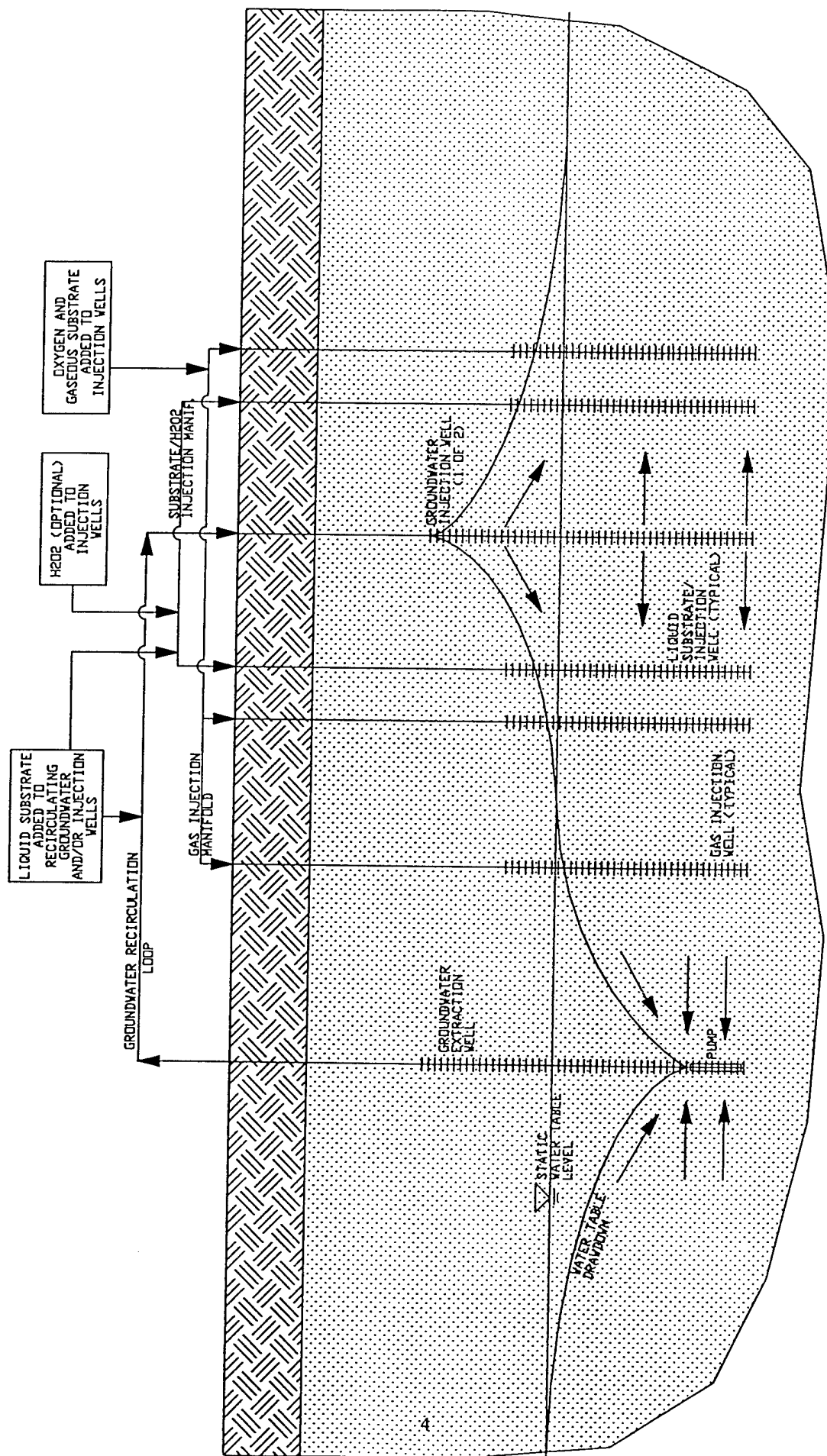


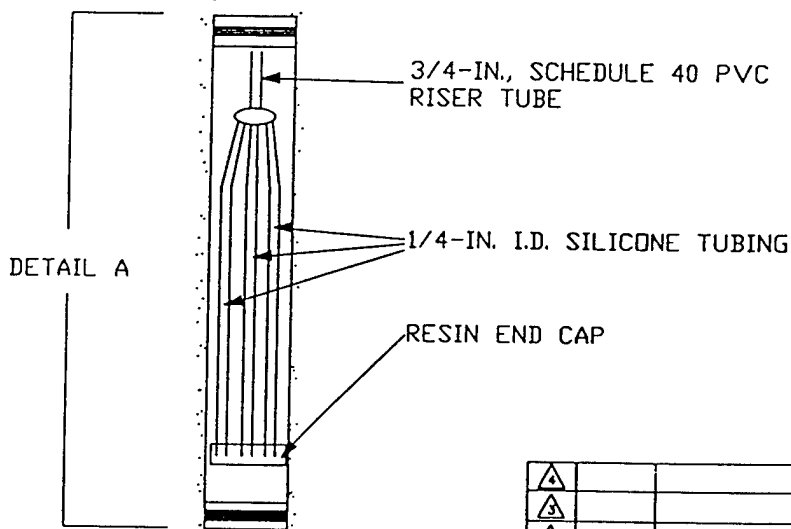
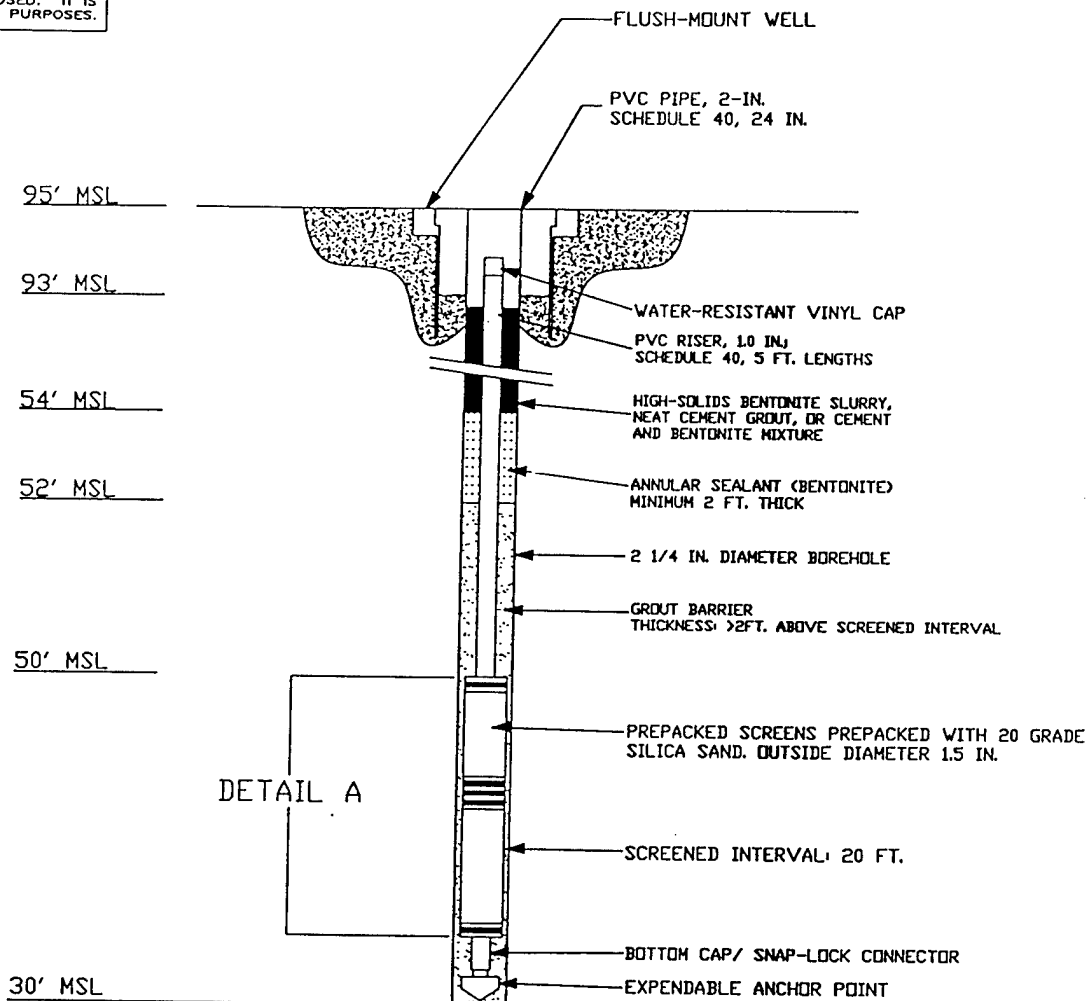
FIGURE 1.3.4  
GROUNDWATER RECIRCULATION & LIQUID AND  
GASEOUS SUBSTRATE INJECTION SYSTEM

NAVAL AIR ENGINEERING STATION  
LAKEHURST, NEW JERSEY



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					FILE # 1000-2-200



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FIGURE 1.3.5  
SMALL DIAMETER GASEOUS  
SUBSTRATE INJECTION WELL  
NAVAL AIR ENGINEERING STATION  
LAKEHURST, NEW JERSEY

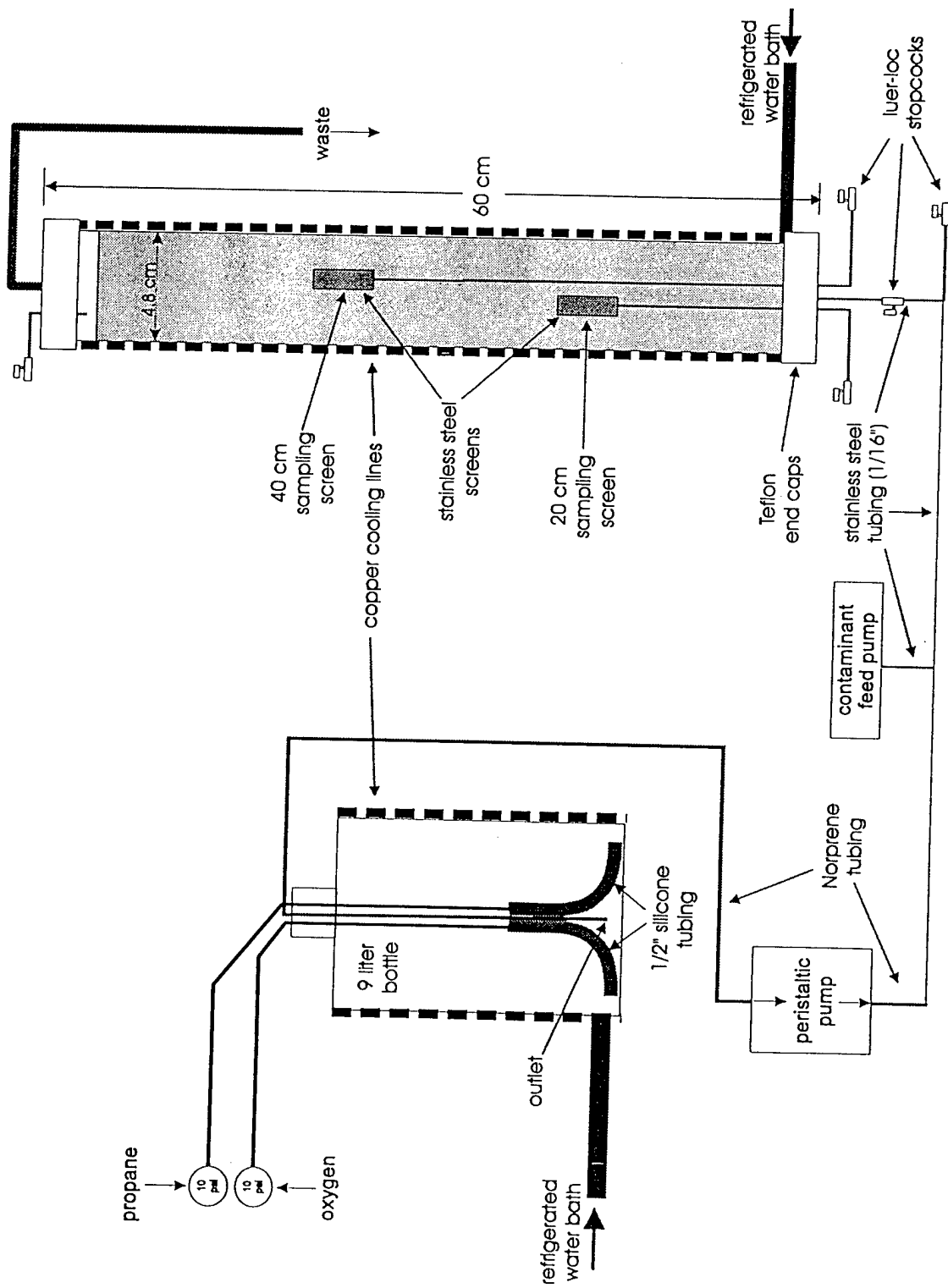
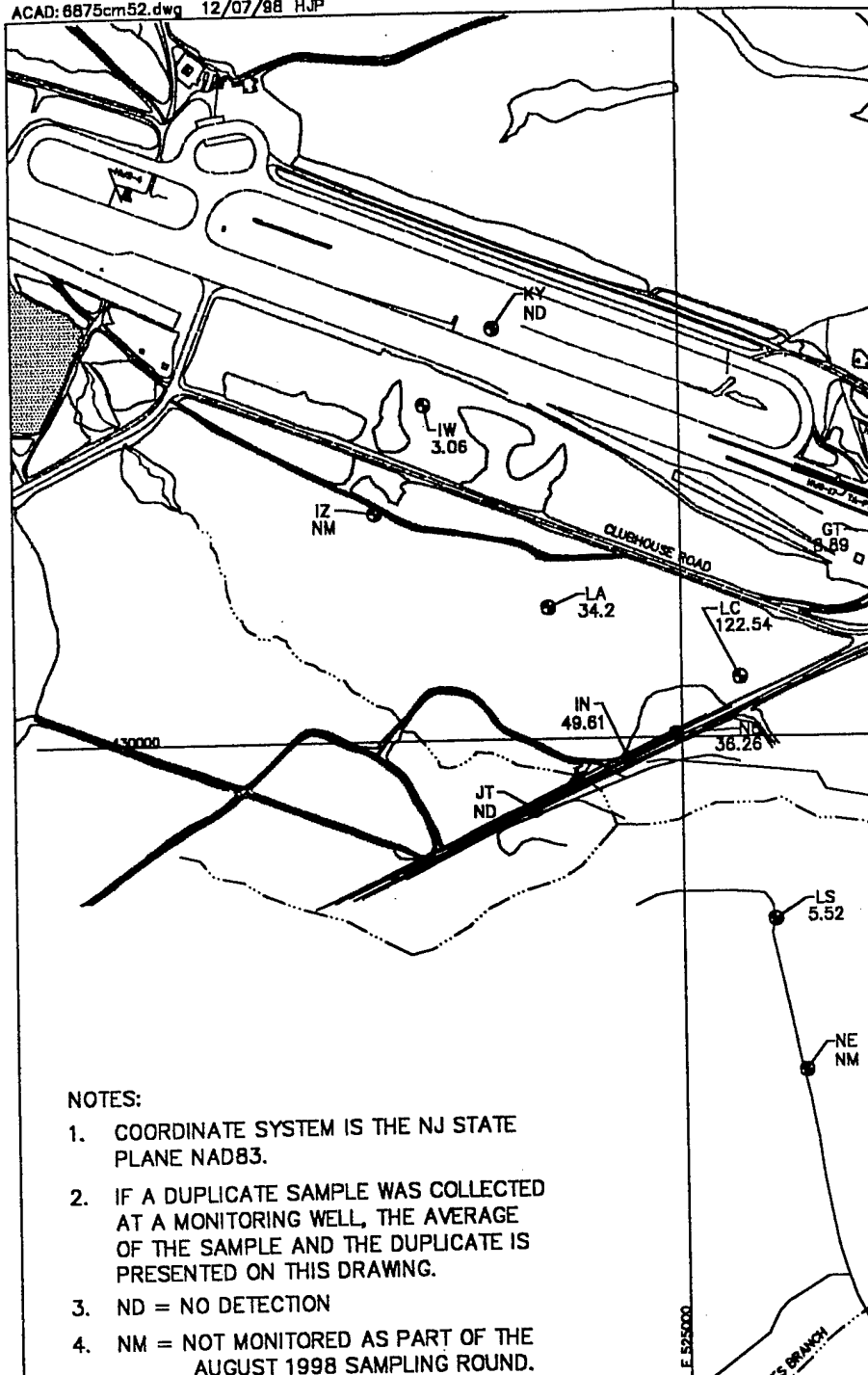


Figure 2.1.2.1. Laboratory-scale model aquifer column.

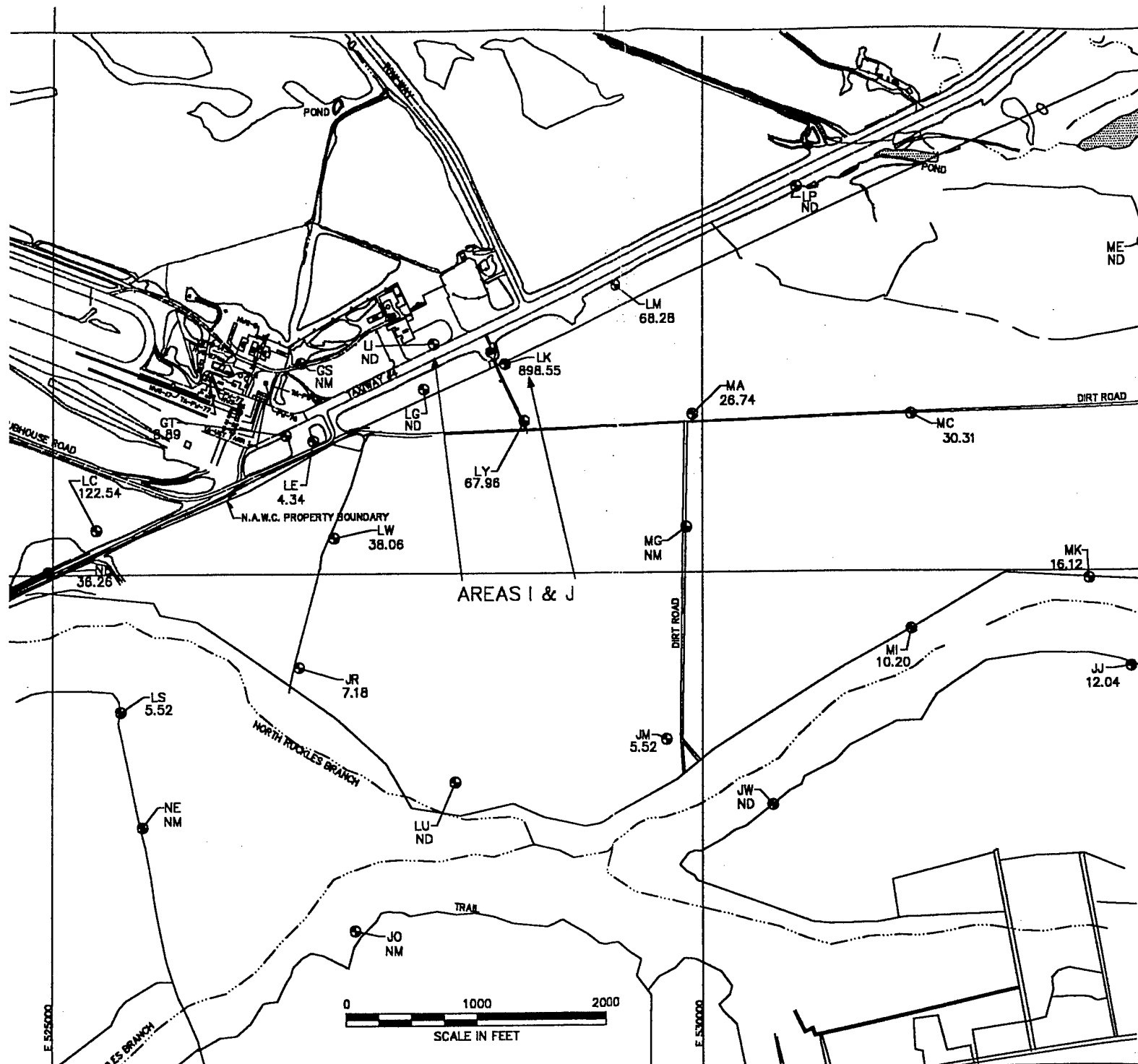



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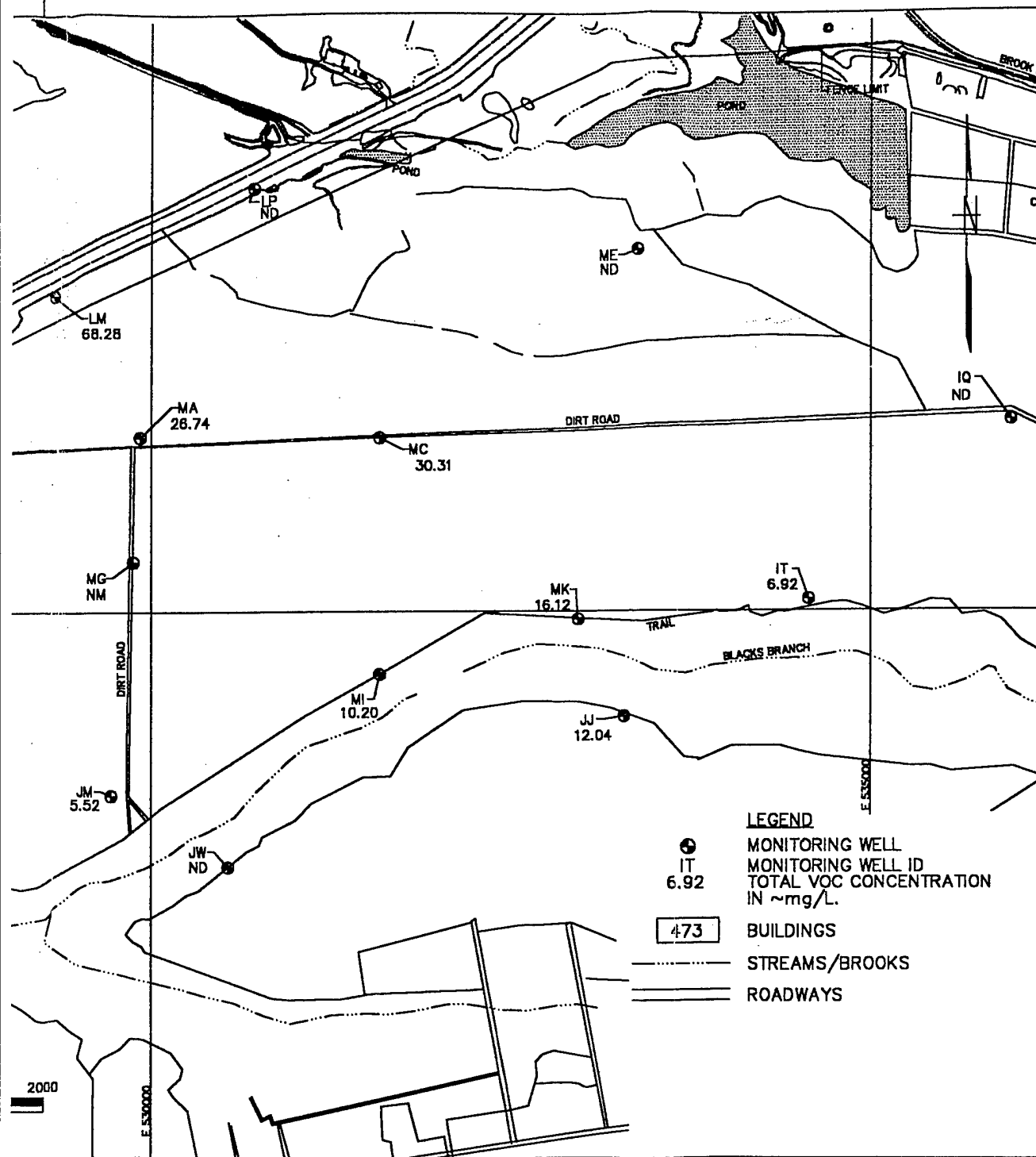
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				COST/SCHED-AREA		
				SCALE AS NOTED		

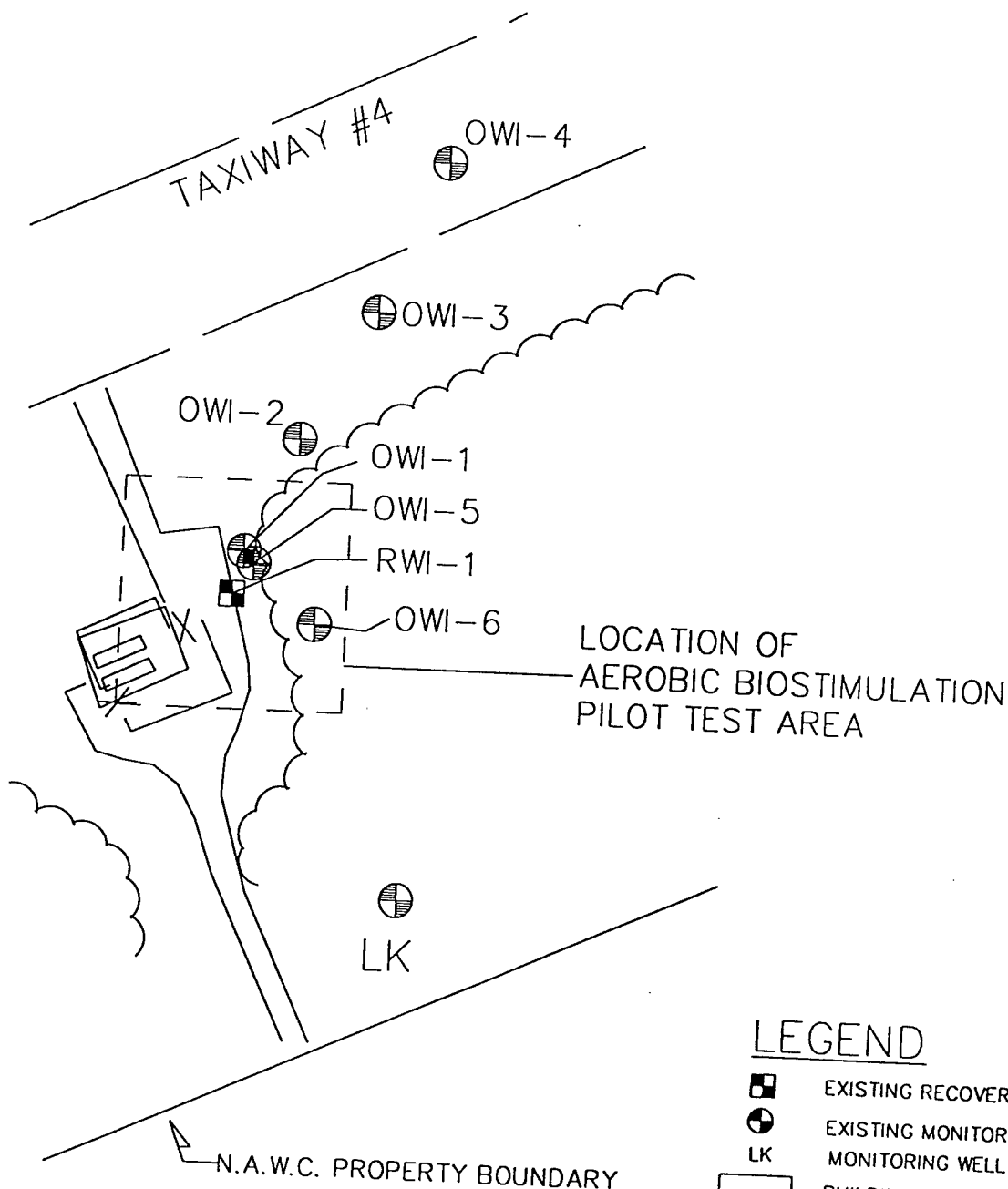
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COST/SCHED-AREA		LOCATION OF AREAS I & J GROUNDWATER NATURAL RESTORATION STUDY NAVAL AIR ENGINEERING STATION LAKEHURST, NEW JERSEY	APPROVED BY	DATE
SCALE AS NOTED			DRAWING NO.	FIGURE 2.2.1.1
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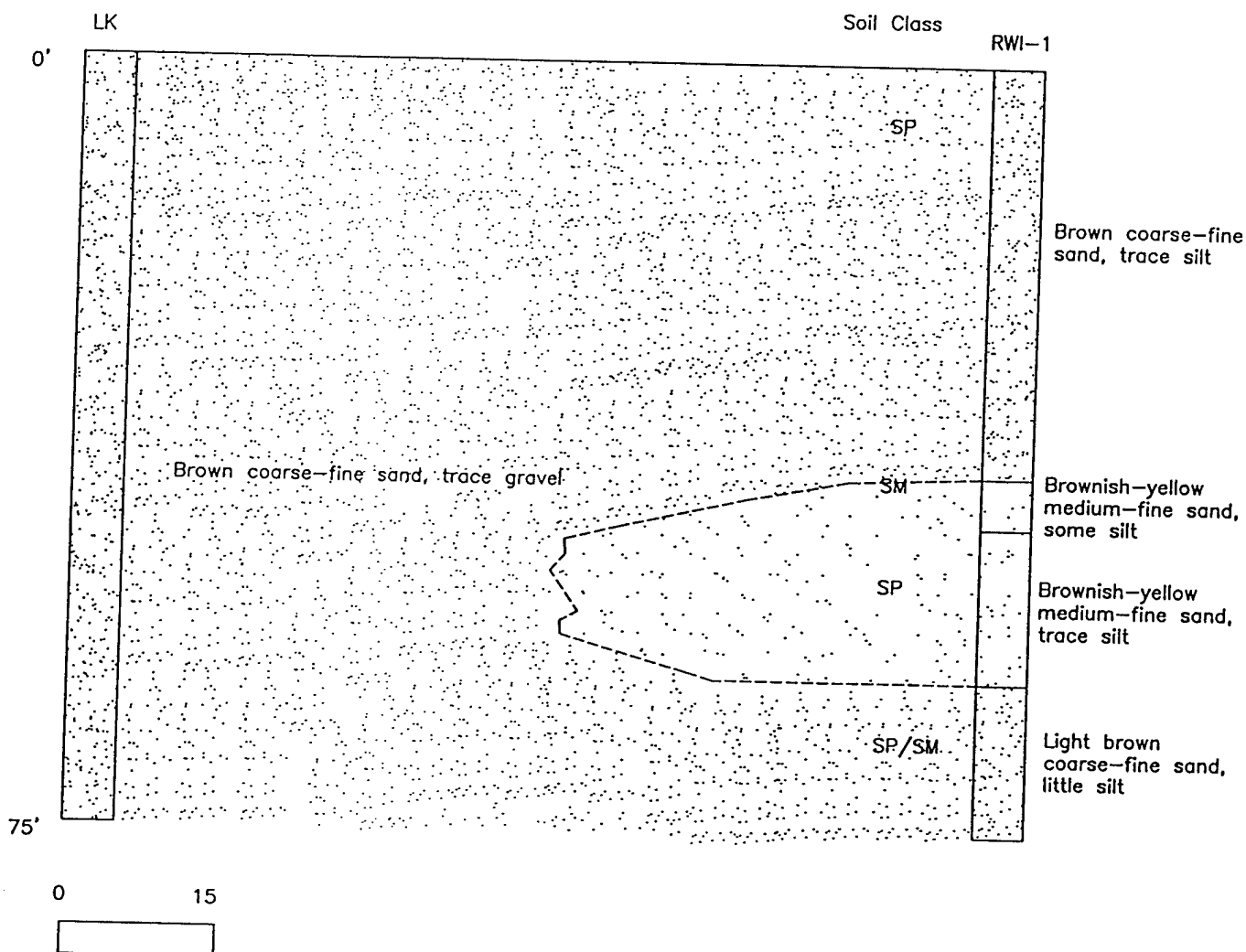
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					FIGURE 2.2.1.2

FIGURE 2.2.1.2  
8 LOCATION OF AEROBIC BIOSTIMULATION PILOT TEST AREA  
NAVAL AIR ENGINEERING STATION  
LAKEHURST, NEW JERSEY

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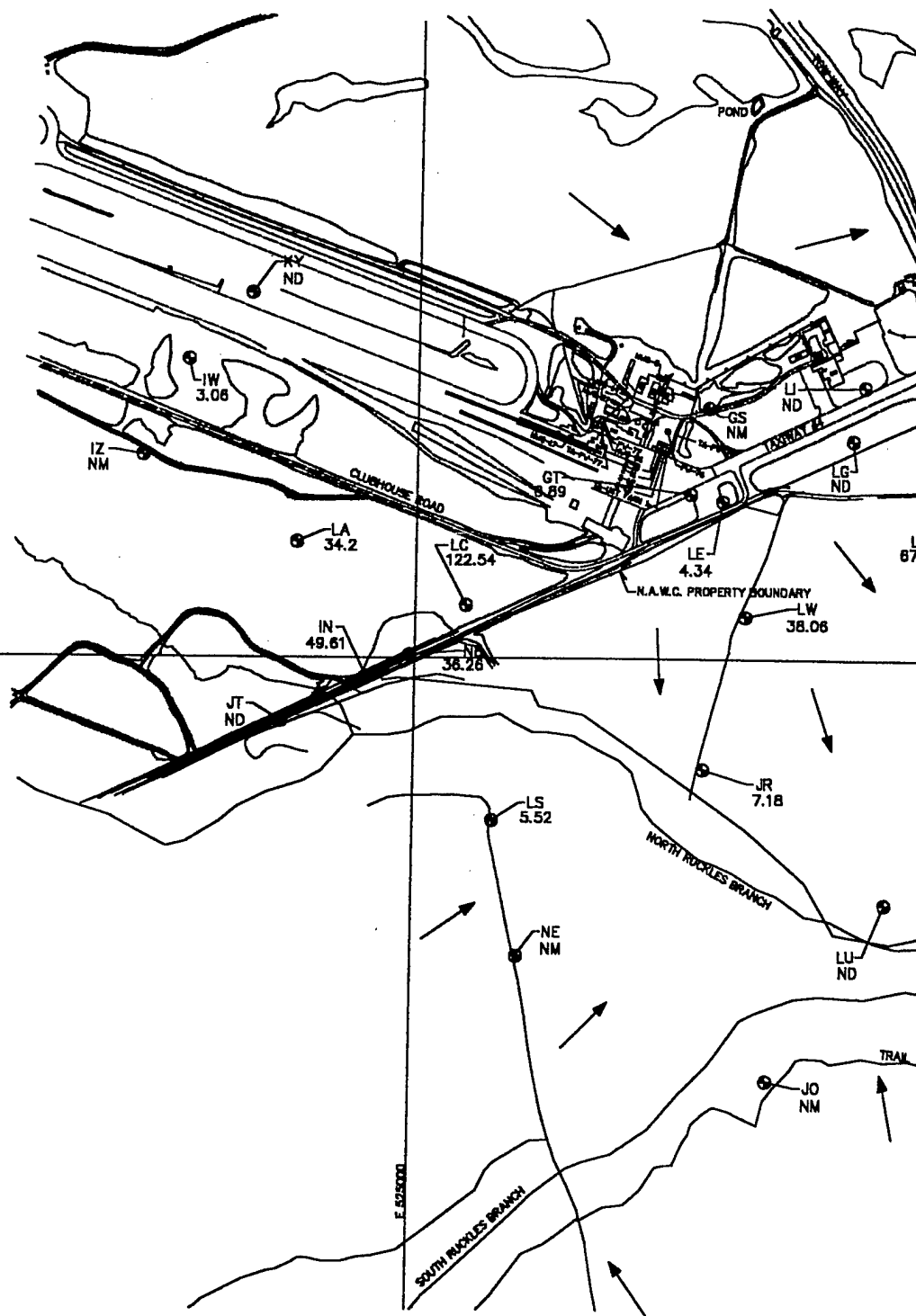


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FROM WELL LK TO RWI-1					FIGURE 2.2.1.3	
NAVAL AIR ENGINEERING STATION					FILE #	
LAKEHURST, NEW JERSEY					FIGURE 2.2.1.3	

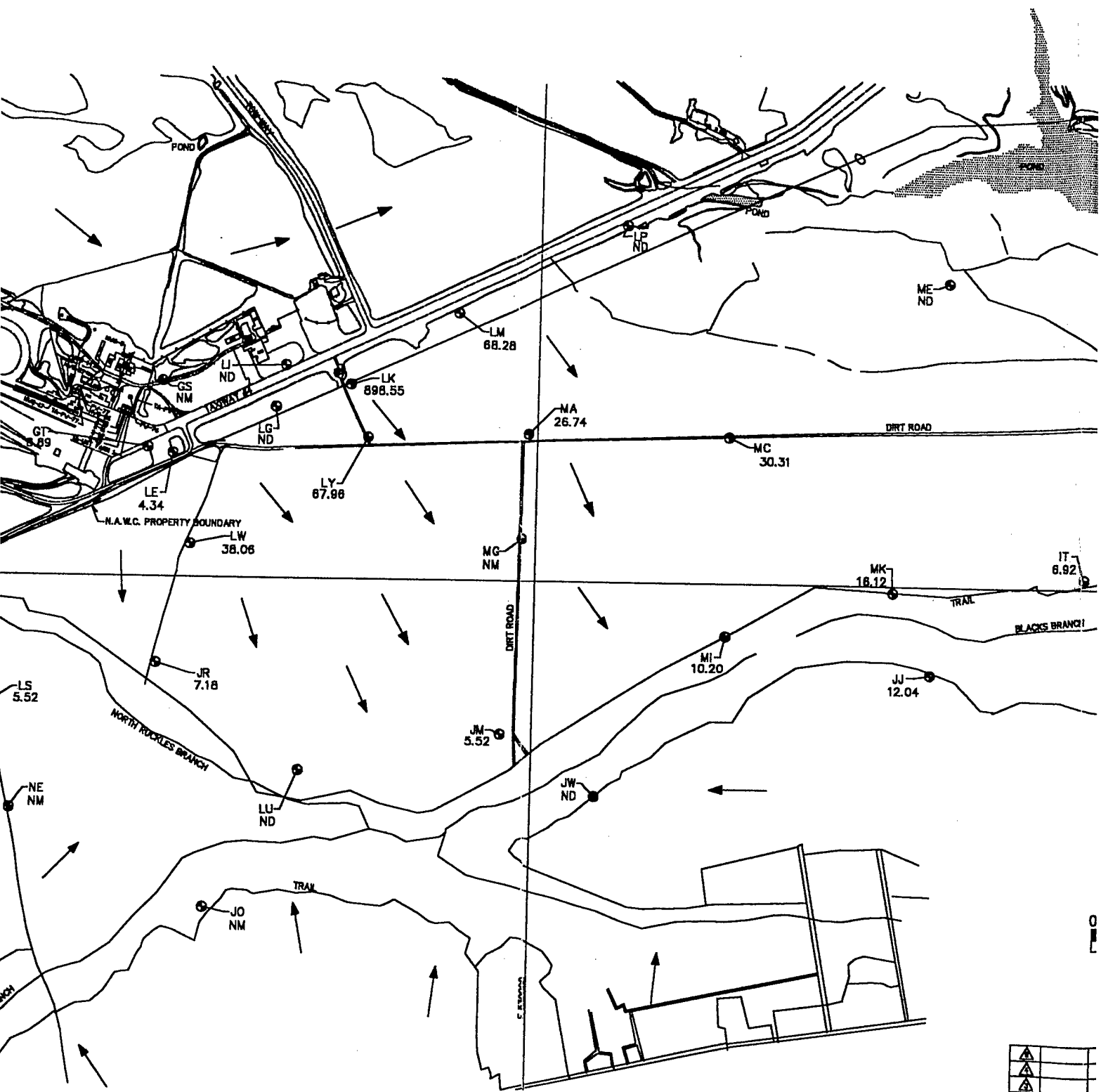


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SOURCE: TETRA TECH BASE MAP



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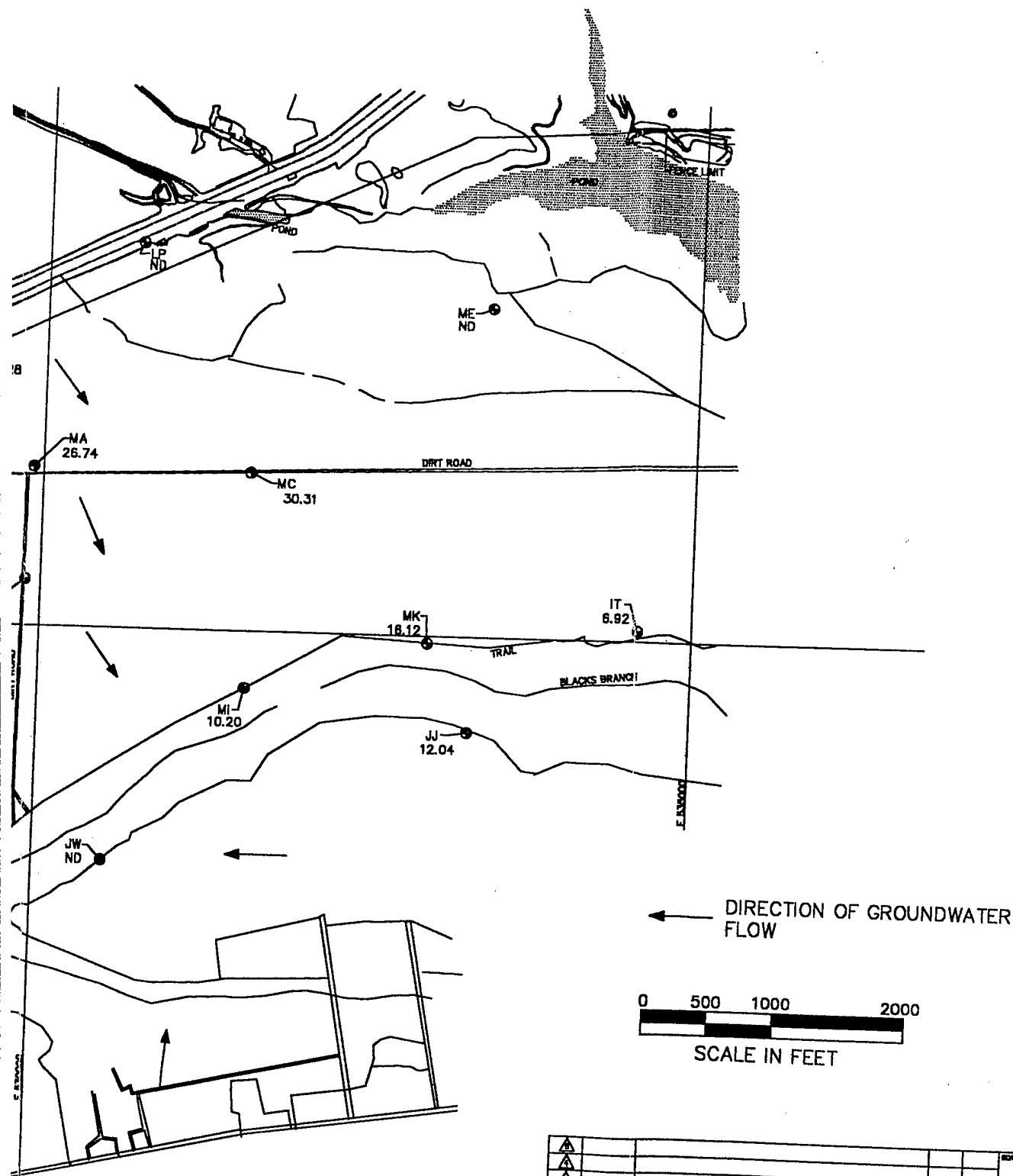


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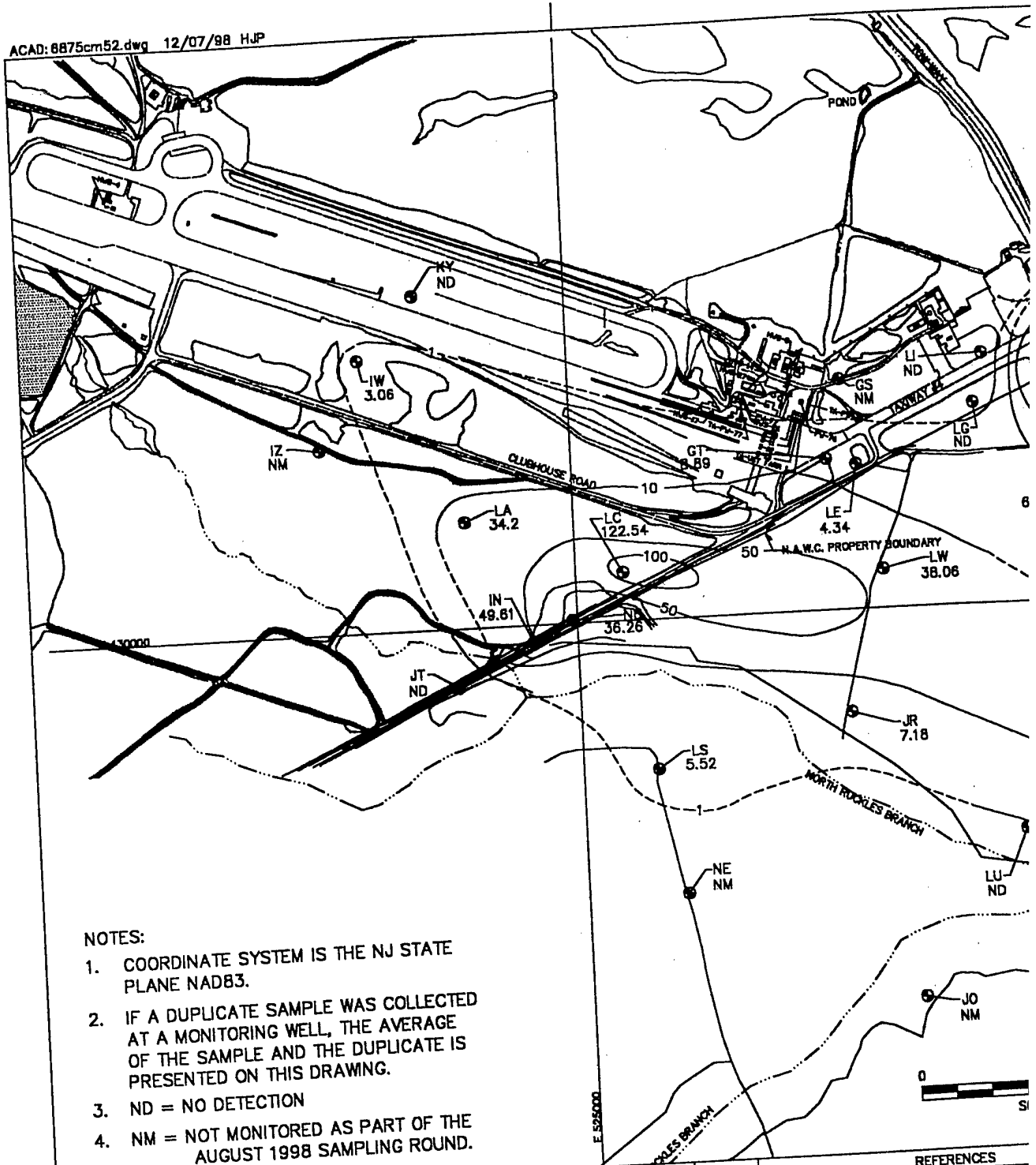
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10							FIGURE 2.2.1.4
11							FIGURE 2-2-1-4



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FIGURE 2.2.1.4  
GROUNDWATER FLOW MAP  
NAVAL AIR ENGINEERING STATION  
LAKEHURST, NEW JERSEY



NOTES:

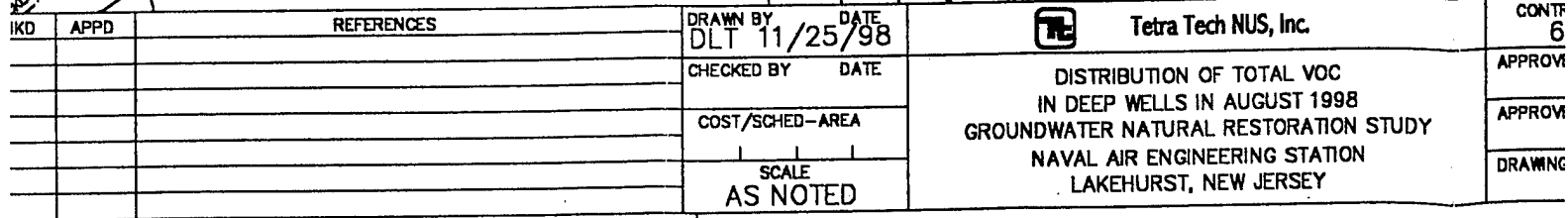
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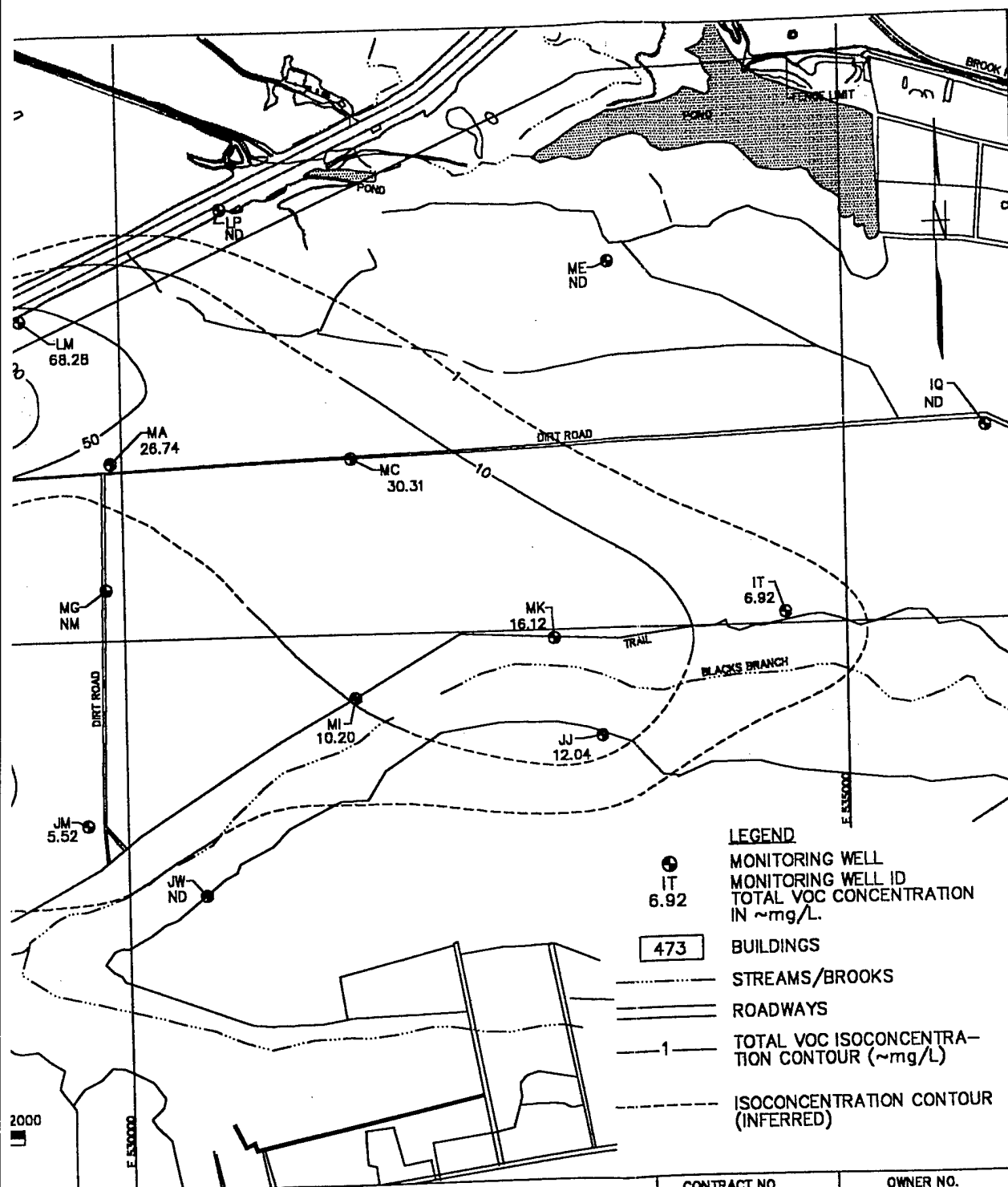
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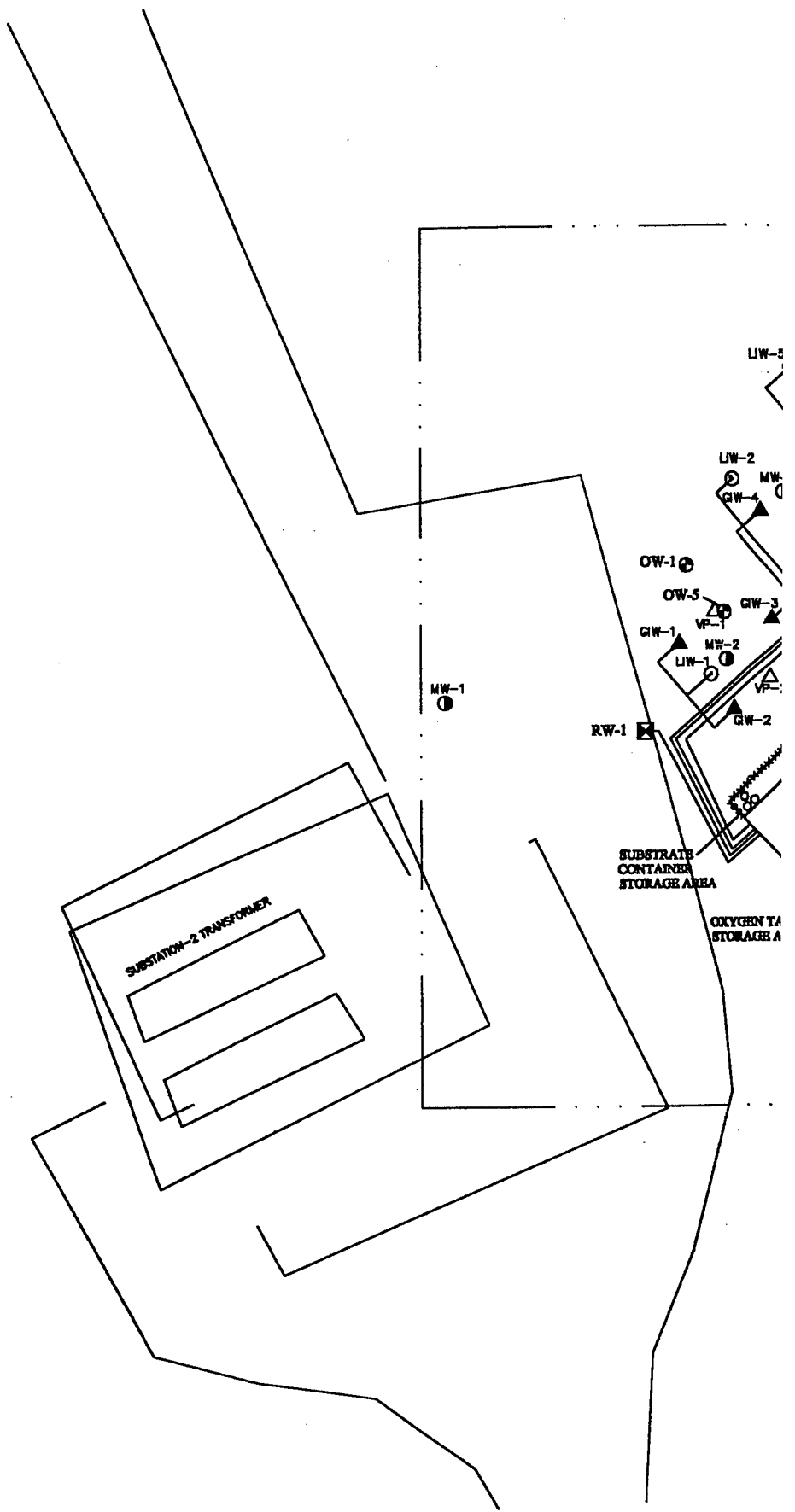




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SCALE AS NOTED			DRAWING NO. FIGURE 2.2.1.5	REV. 0

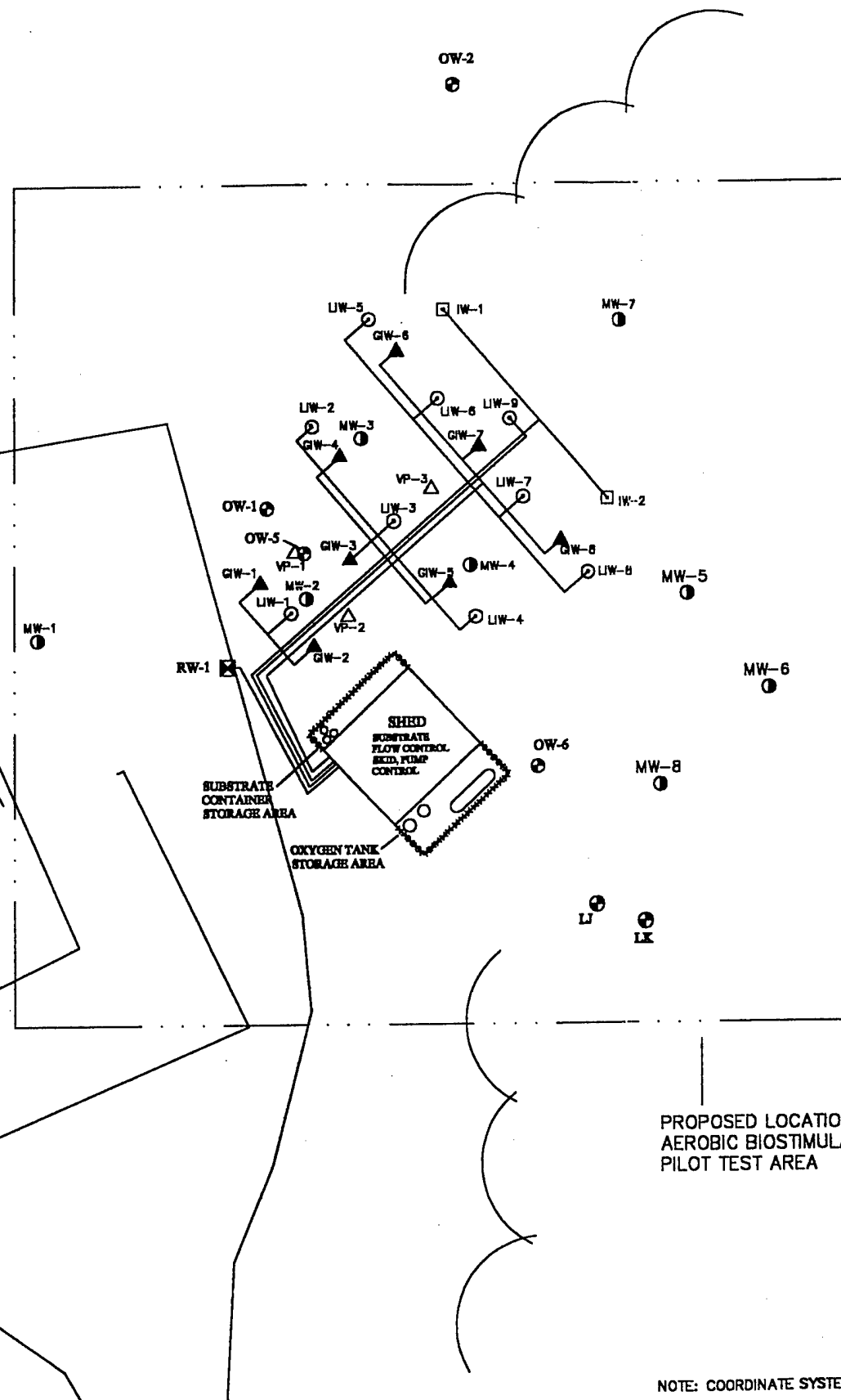


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1



- LEGEND**
- BUILDINGS
  - ROADWAYS
  - EXISTING GROUNDWATER
  - GROUNDWATER INJECTION
  - EXISTING GROUNDWATER
  - PROPOSED GROUNDWATER
  - ◉ LIQUID SUBSTRATE INJECTION
  - ▲ OXYGEN/GASEOUS SUBSTRATE
  - △ VAPOR MONITORING

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SCALE IN FEET

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








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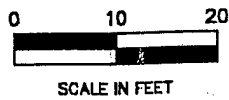
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NAVAL AIR LAKE








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①

- LEGEND**
-  BUILDINGS
  -  ROADWAYS
  -  EXISTING GROUNDWATER EXTRACTION WELL (1)
  -  GROUNDWATER INJECTION WELL (2)
  -  EXISTING GROUNDWATER OBSERVATION WELL
  -  PROPOSED GROUNDWATER MONITORING WELL (3)
  -  LIQUID SUBSTRATE INJECTION WELL (4)
  -  OXYGEN/GASEOUS SUBSTRATE INJECTION WELL (5)
  -  VAPOR MONITORING PROBE (3)



PROPOSED LOCATION OF  
AEROBIC BIOSTIMULATION  
TEST AREA

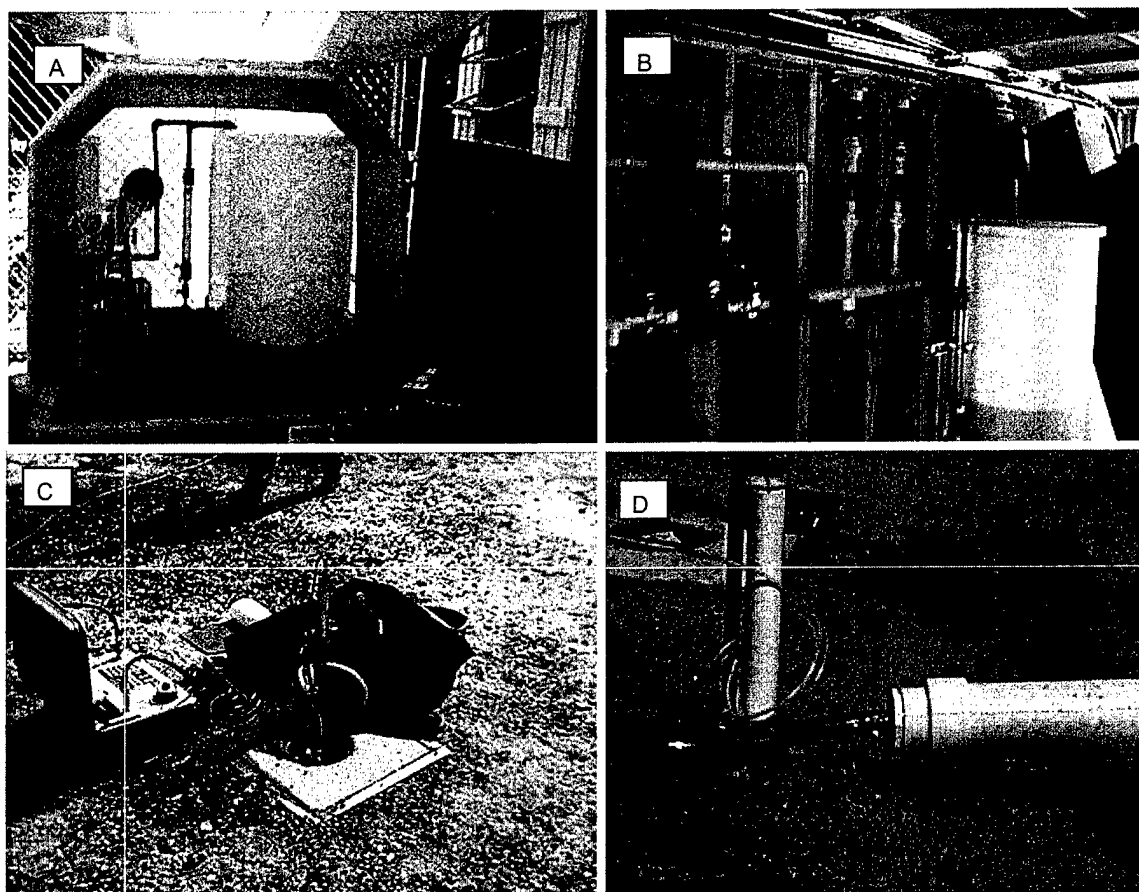
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Figure 2.2.2.1										
TEST PLOT LAYOUT										
NAVAL AIR ENGINEERING STATION										
LAKEHURST, NEW JERSEY										
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3



**Figure 2.2.2.2.** Biostimulation system at Lakehurst NEAS. A) liquid substrate injection system, B) Nutrient mixing and injection system, C) finished monitoring well and low flow sampling and monitoring system, D) Gaseous substrate injection line.

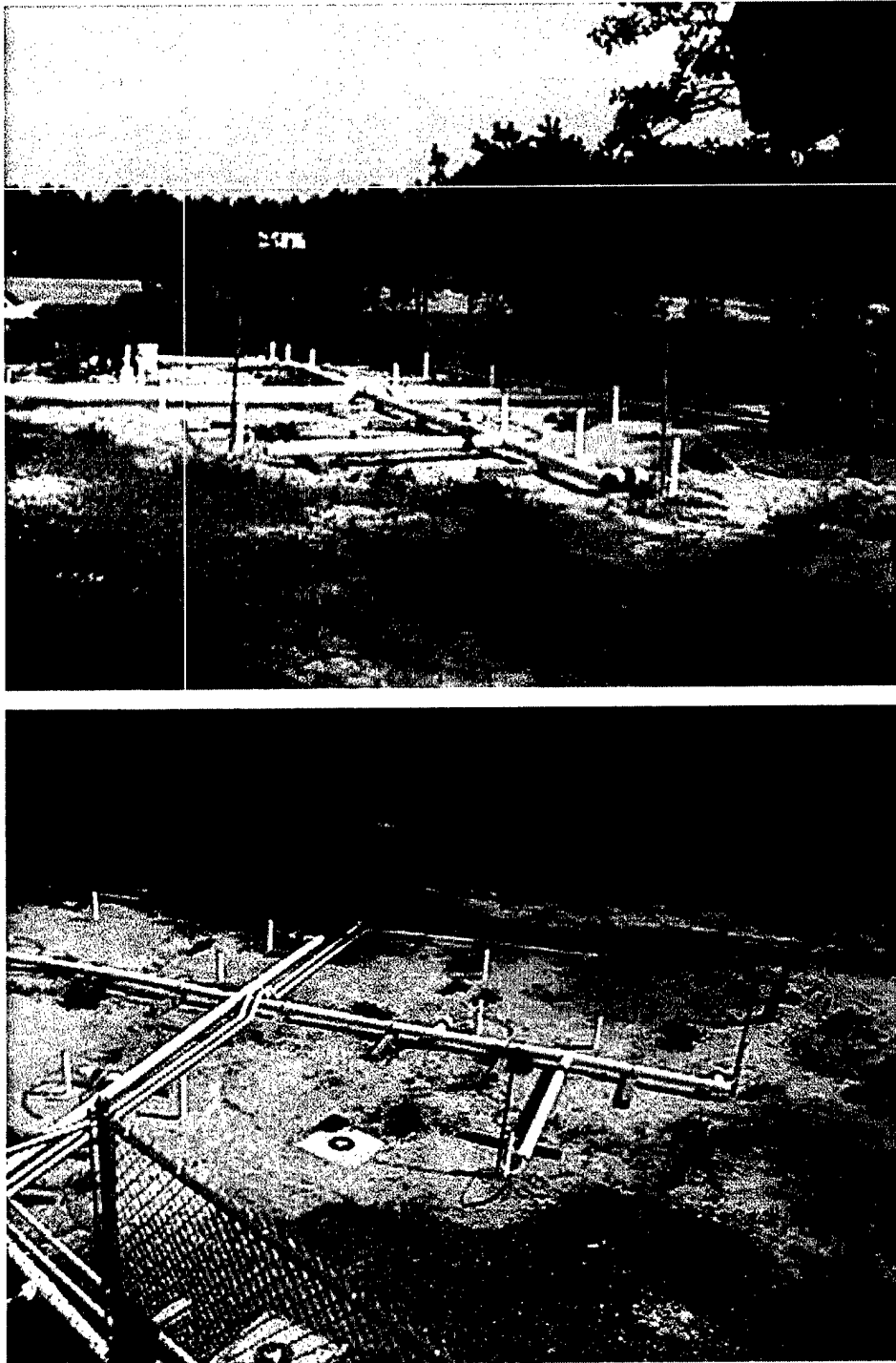


Figure 2.2.2.3. Side view and overhead view of the test plot layout at Lakehurst NAES.

Figure 3.1.1. Lakehurst Microcosms:  
Propanol Concentration

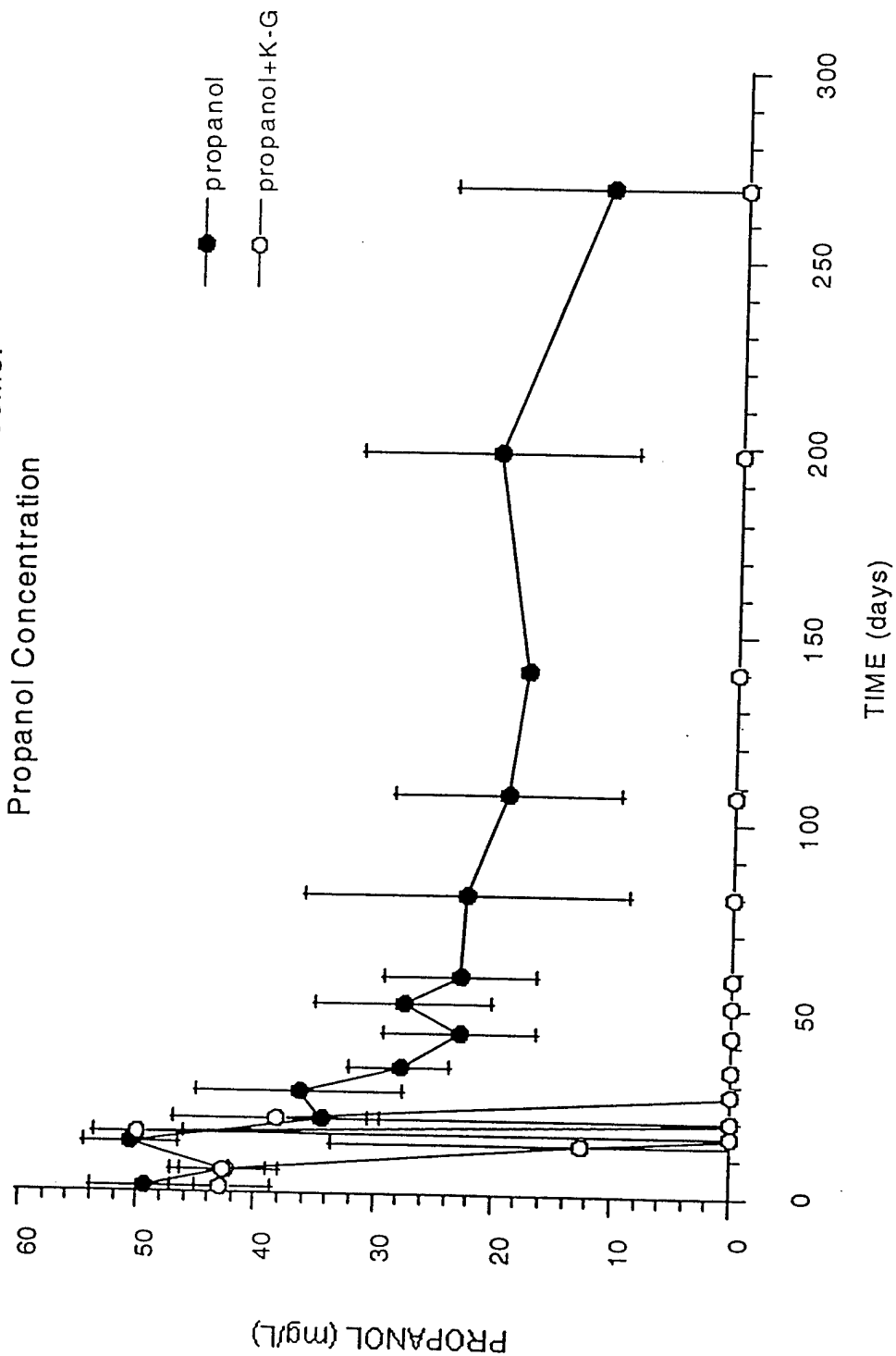




Figure 3.1.2. Lakehurst Microcosms:  
Propane Concentration

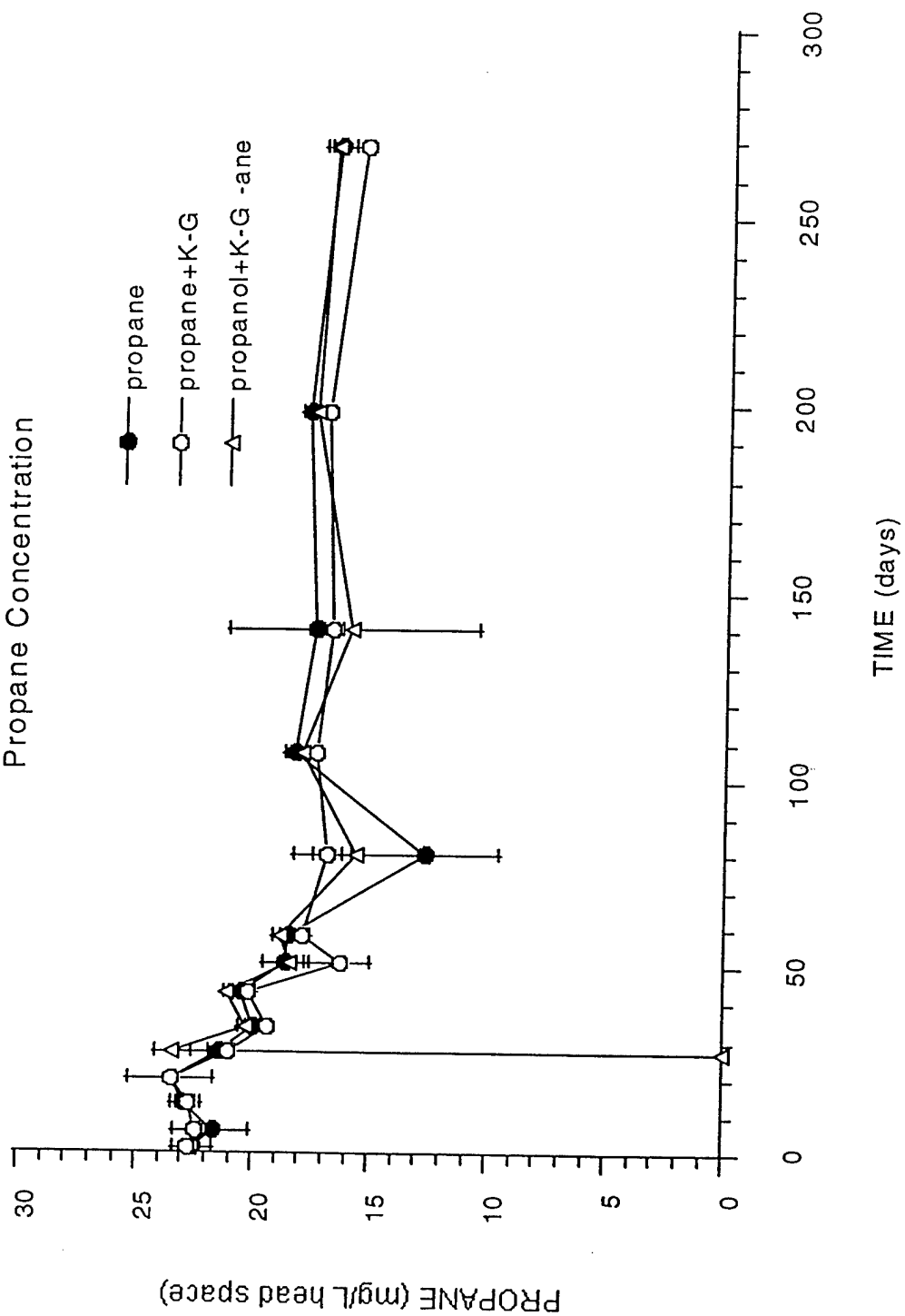


Figure 3.1.3. Lakehurst Microcosms:  
TCE Concentration

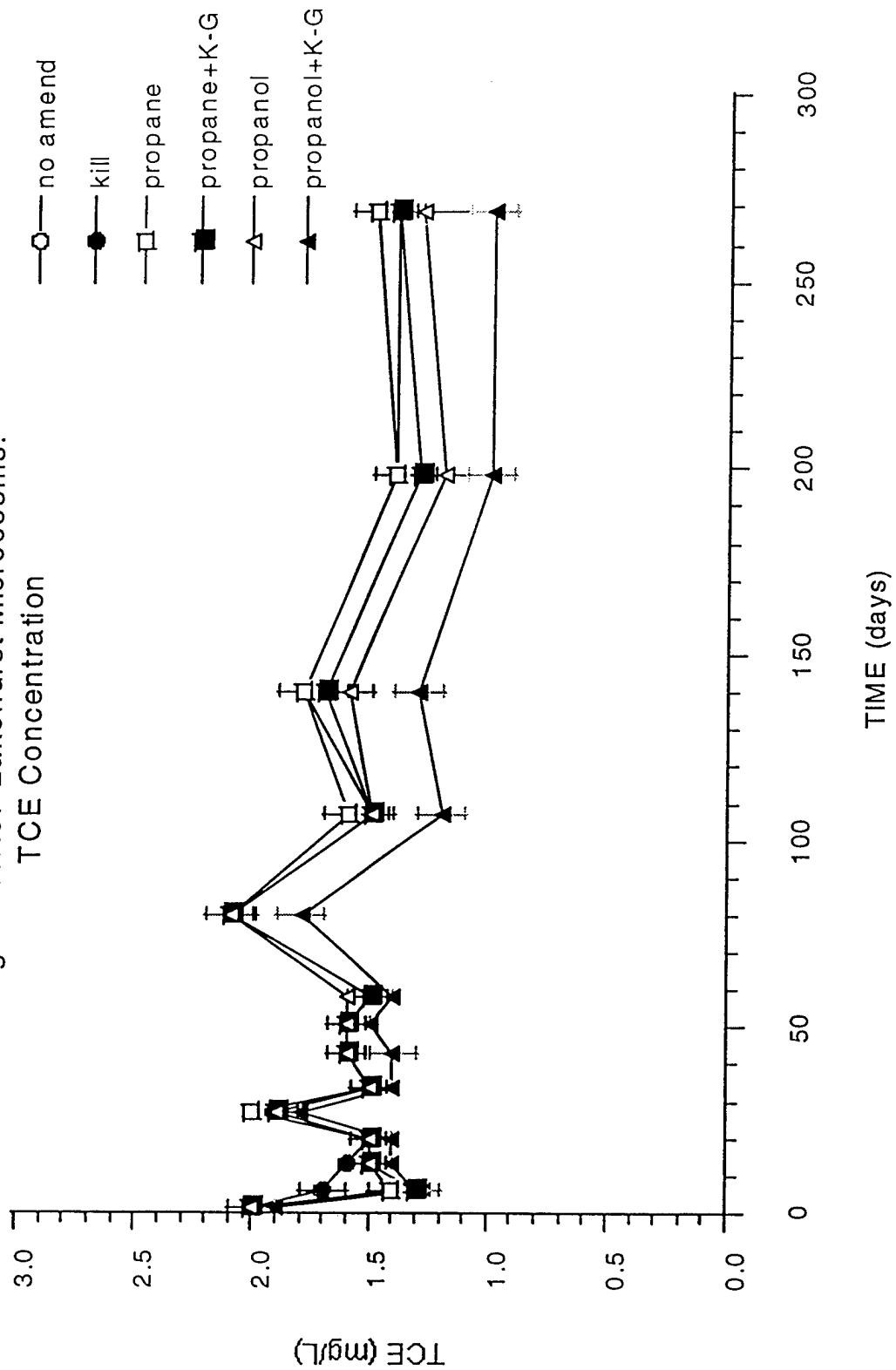


Figure 3.1.4. Diffusion of gases through silicone tubing into groundwater (15 °C).

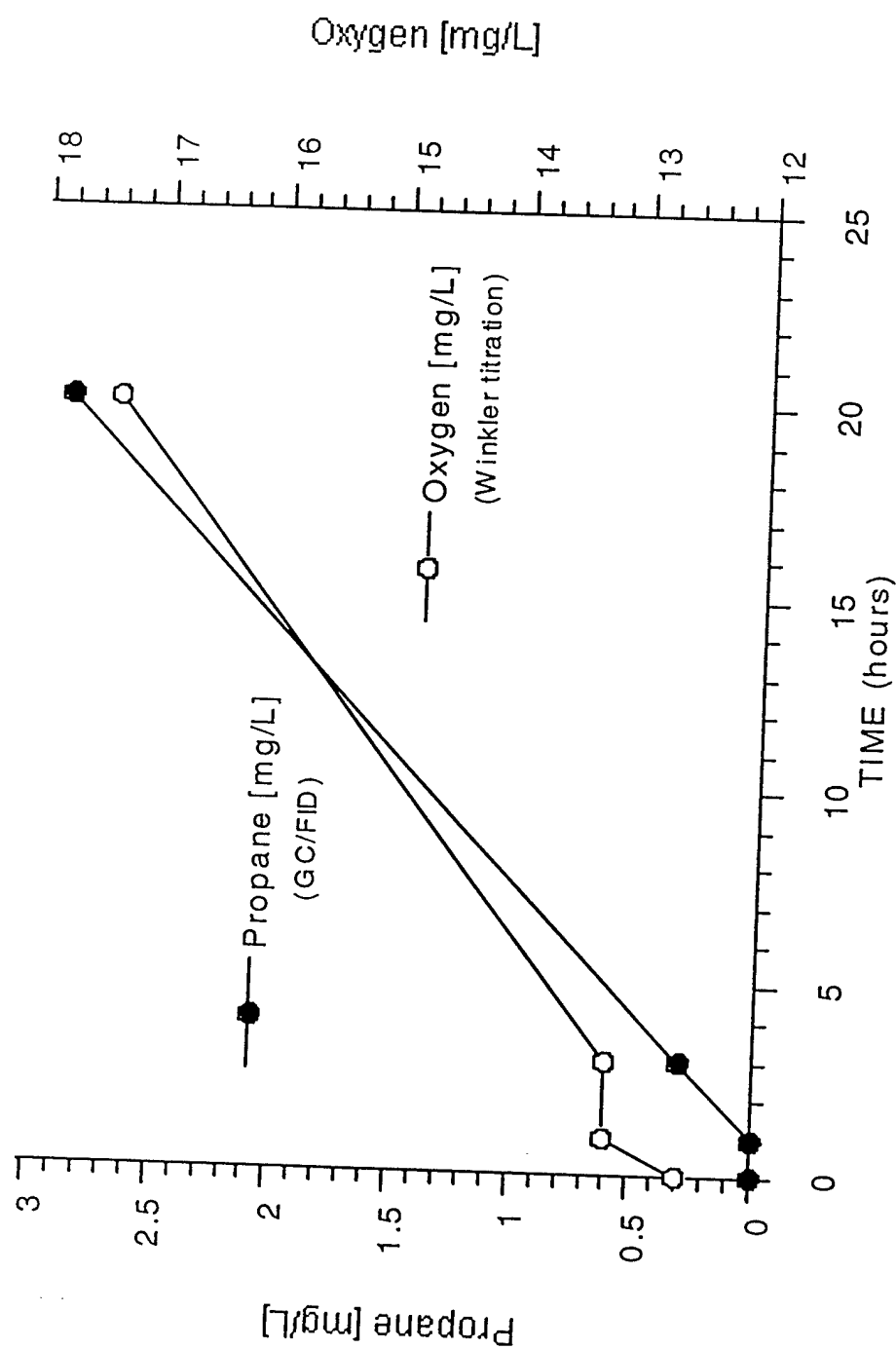


Figure 3.1.5. Lakehurst Columns:  
Dissolved Oxygen (Winkler titration)

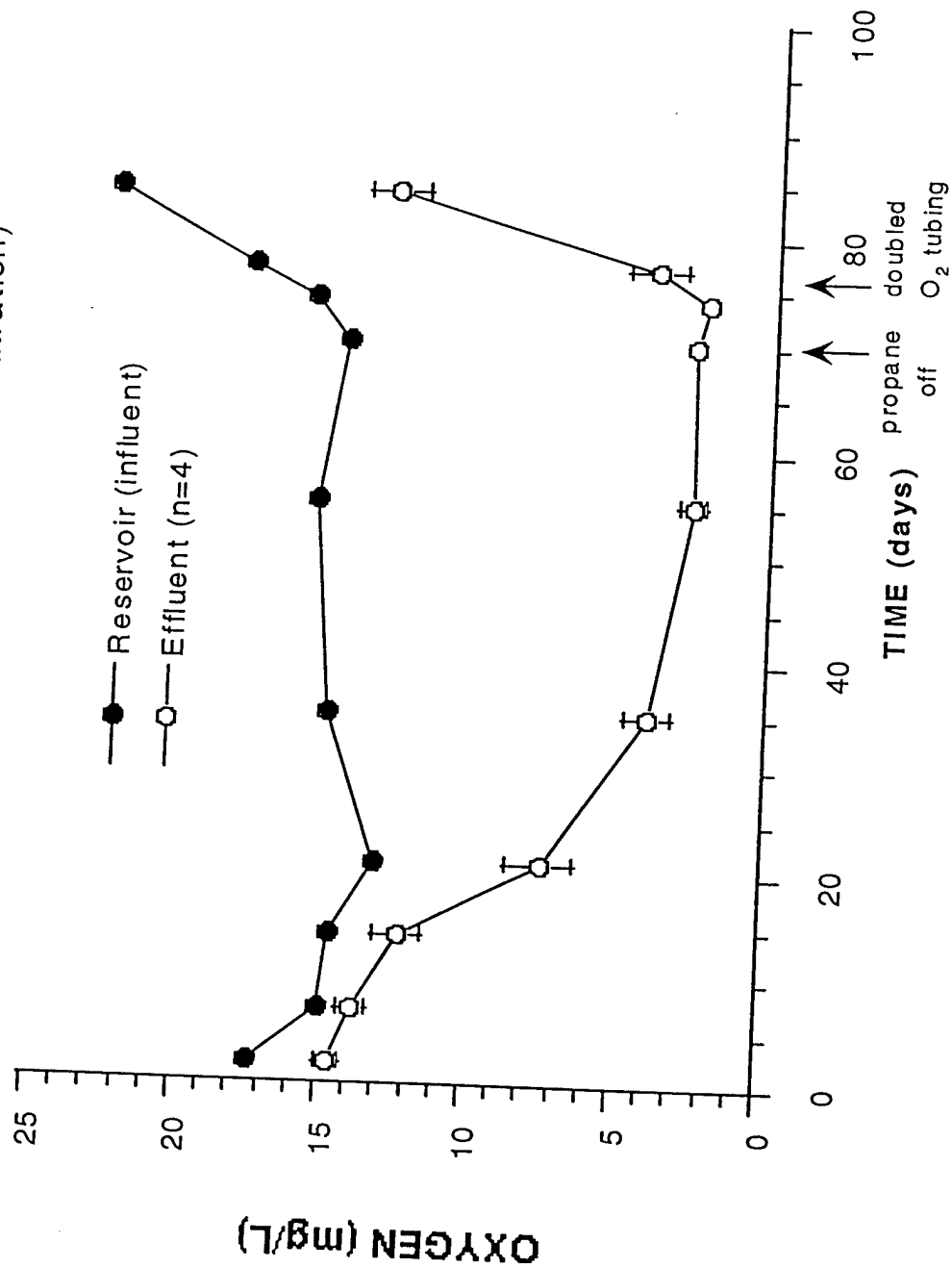
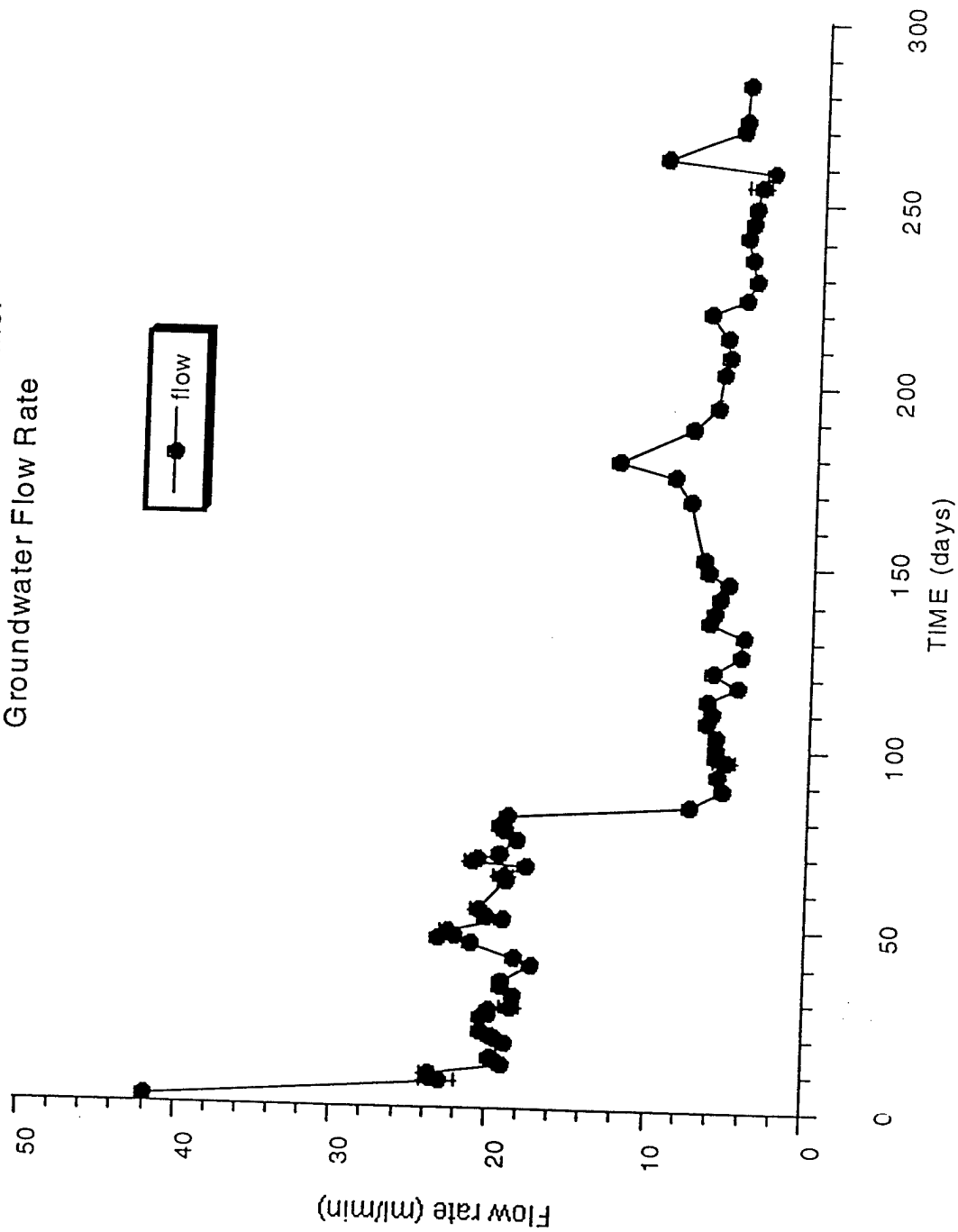


Figure 3.1.6. Lakehurst Columns:  
Groundwater Flow Rate



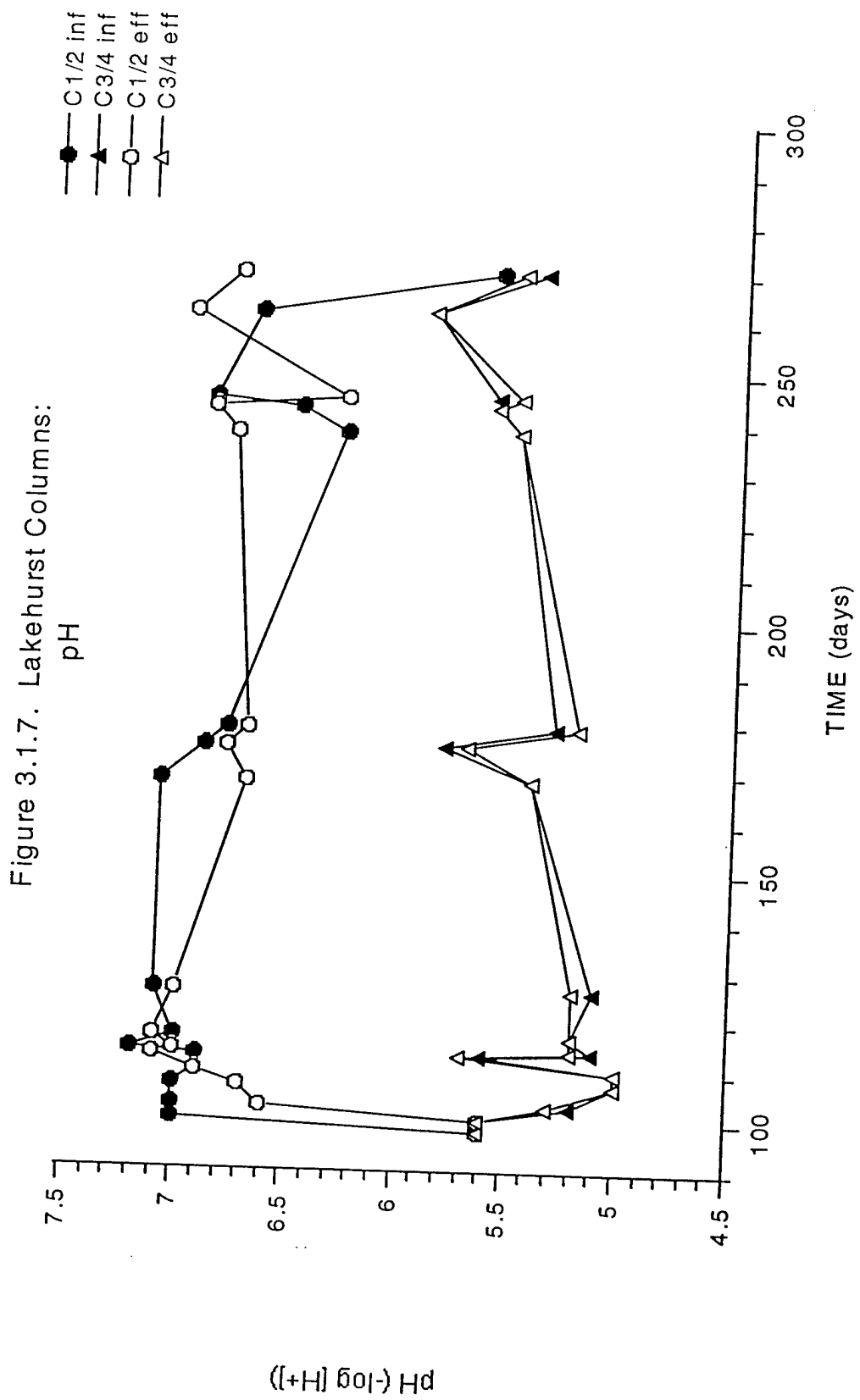


Figure 3.1.8. Lakehurst Columns:  
Propane Concentrations

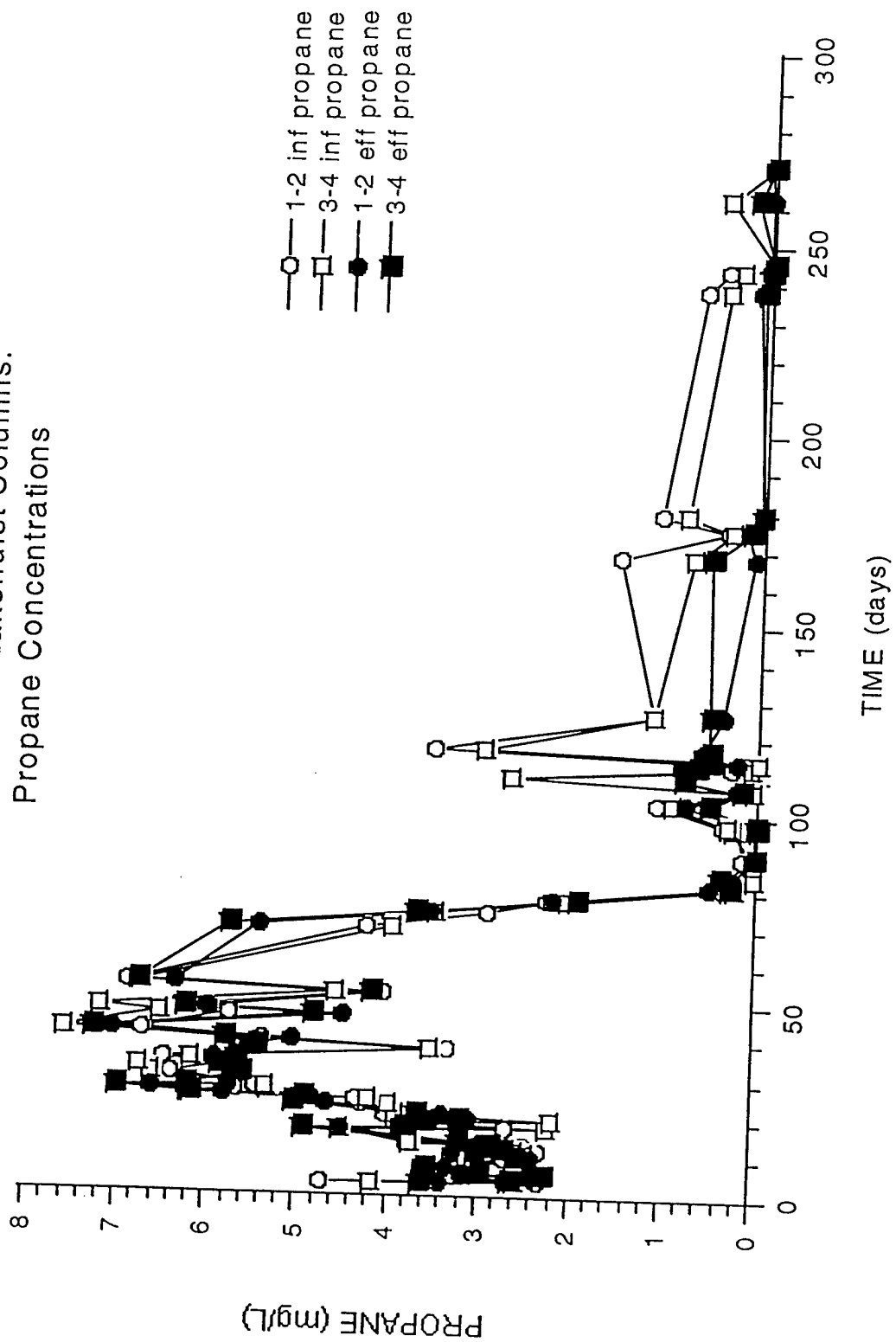


Figure 3.1.9. Lakehurst Columns:  
TCE Concentration

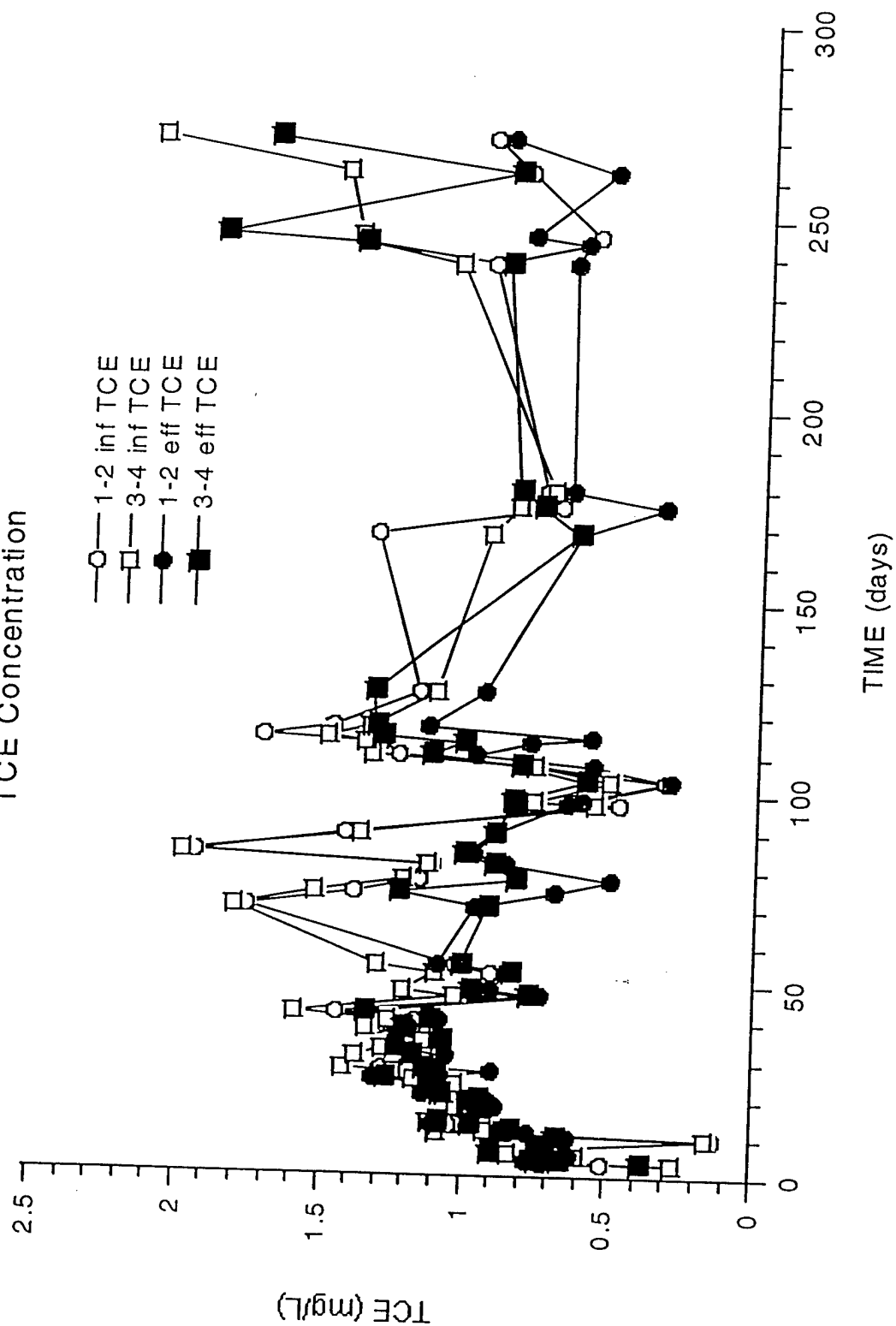




Figure 3.1.10. Lakehurst Columns:  
ENV425 Bioaugmentation (Propane-Oxidizing Bacterium)

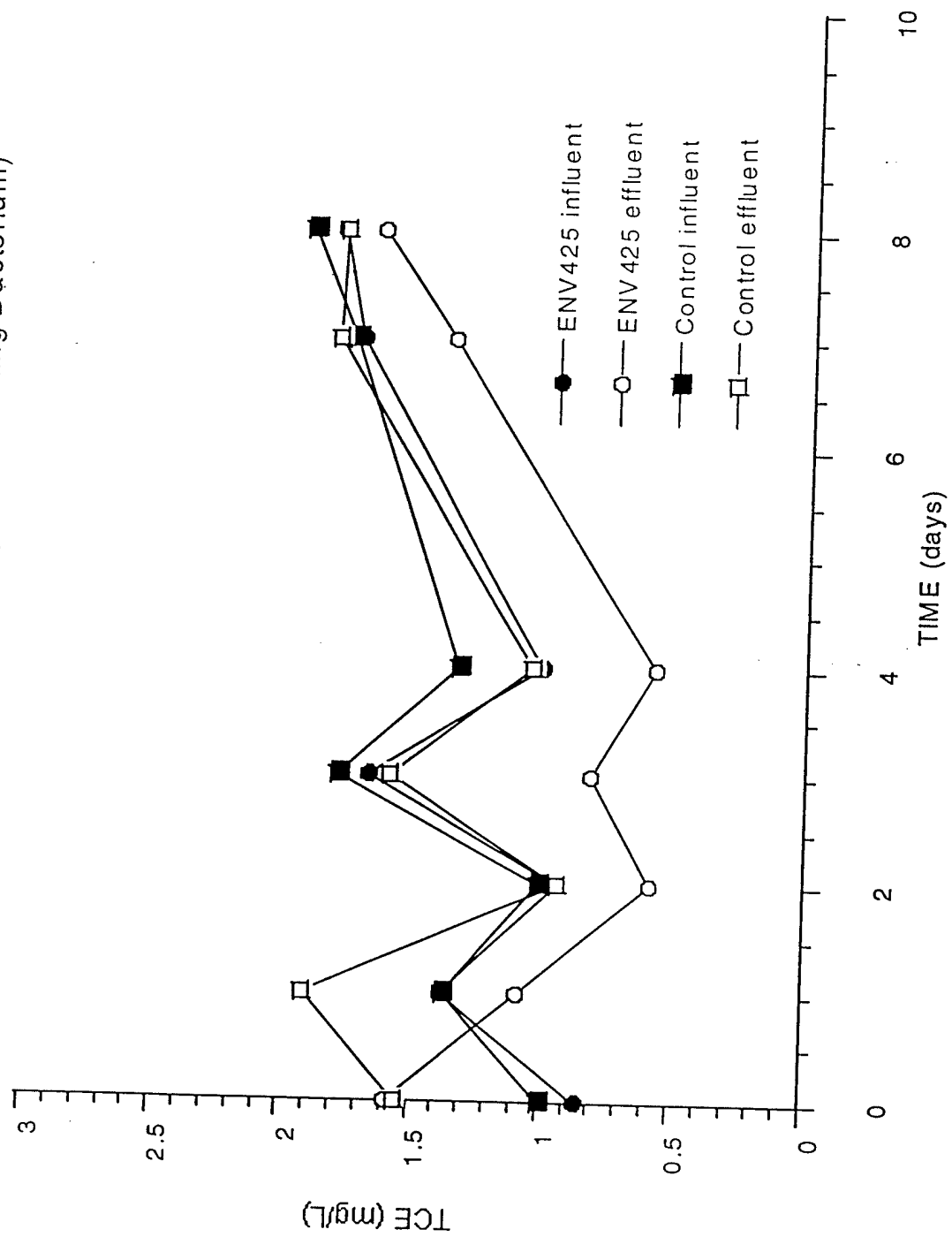


Figure 3.1.11. Lakehurst Columns:  
ENV735 Bioremediation (Toluene Degrader)

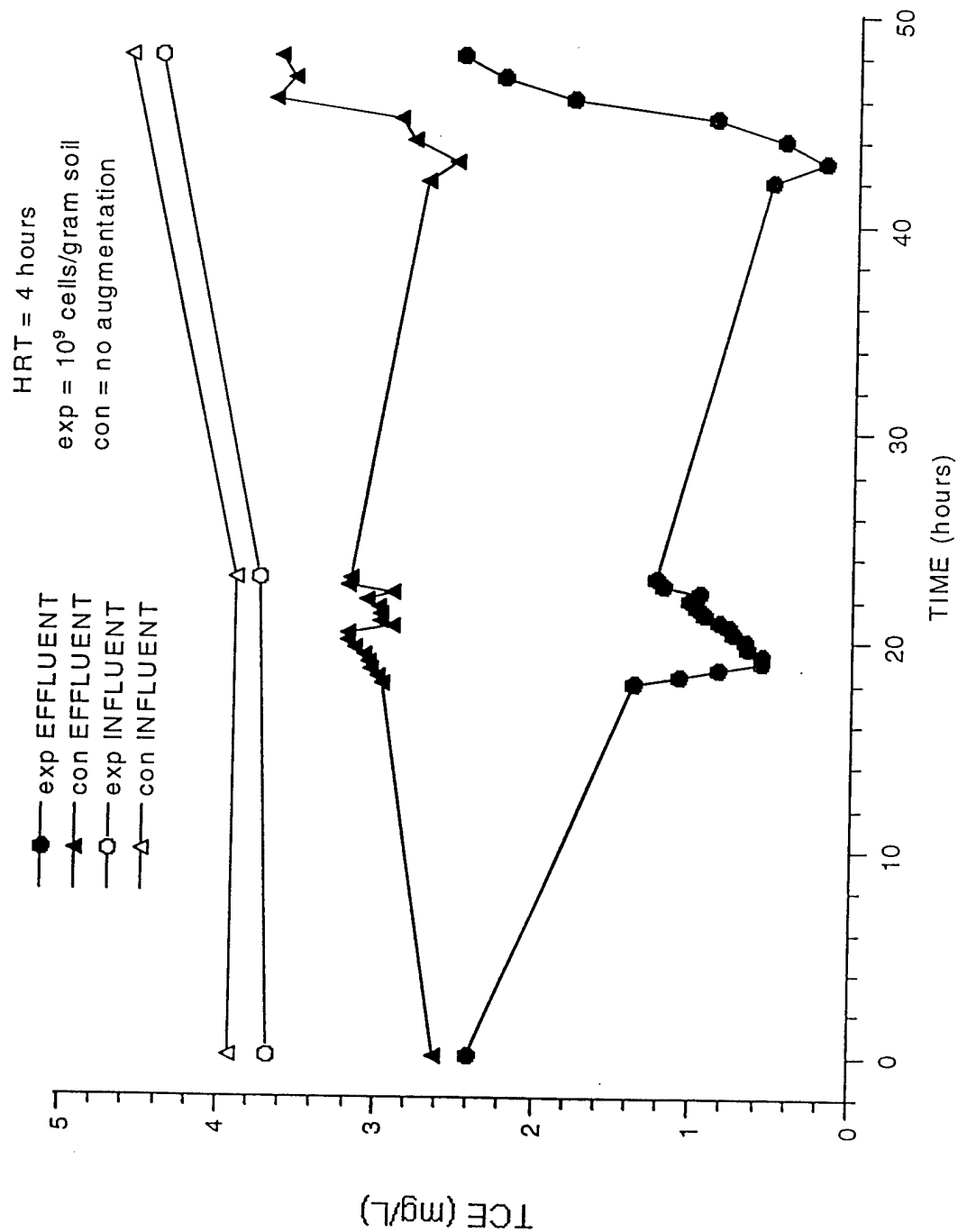


Figure 3.2.2.1  
MW1: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

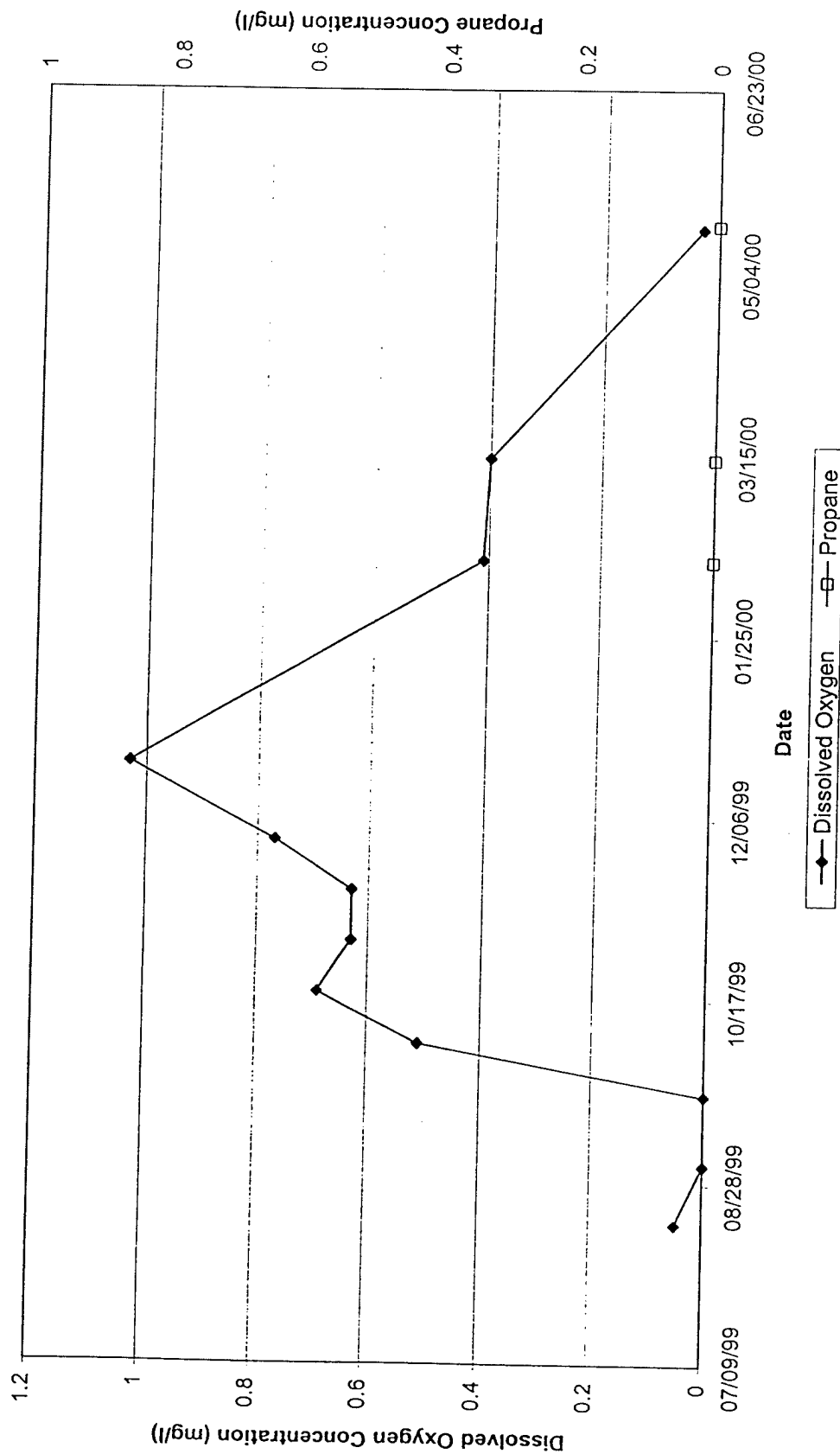


Figure 3.2.2.2  
 MW2: Dissolved Oxygen and Propane Concentrations vs. Time  
 Naval Air Engineering Station  
 Lakehurst, New Jersey

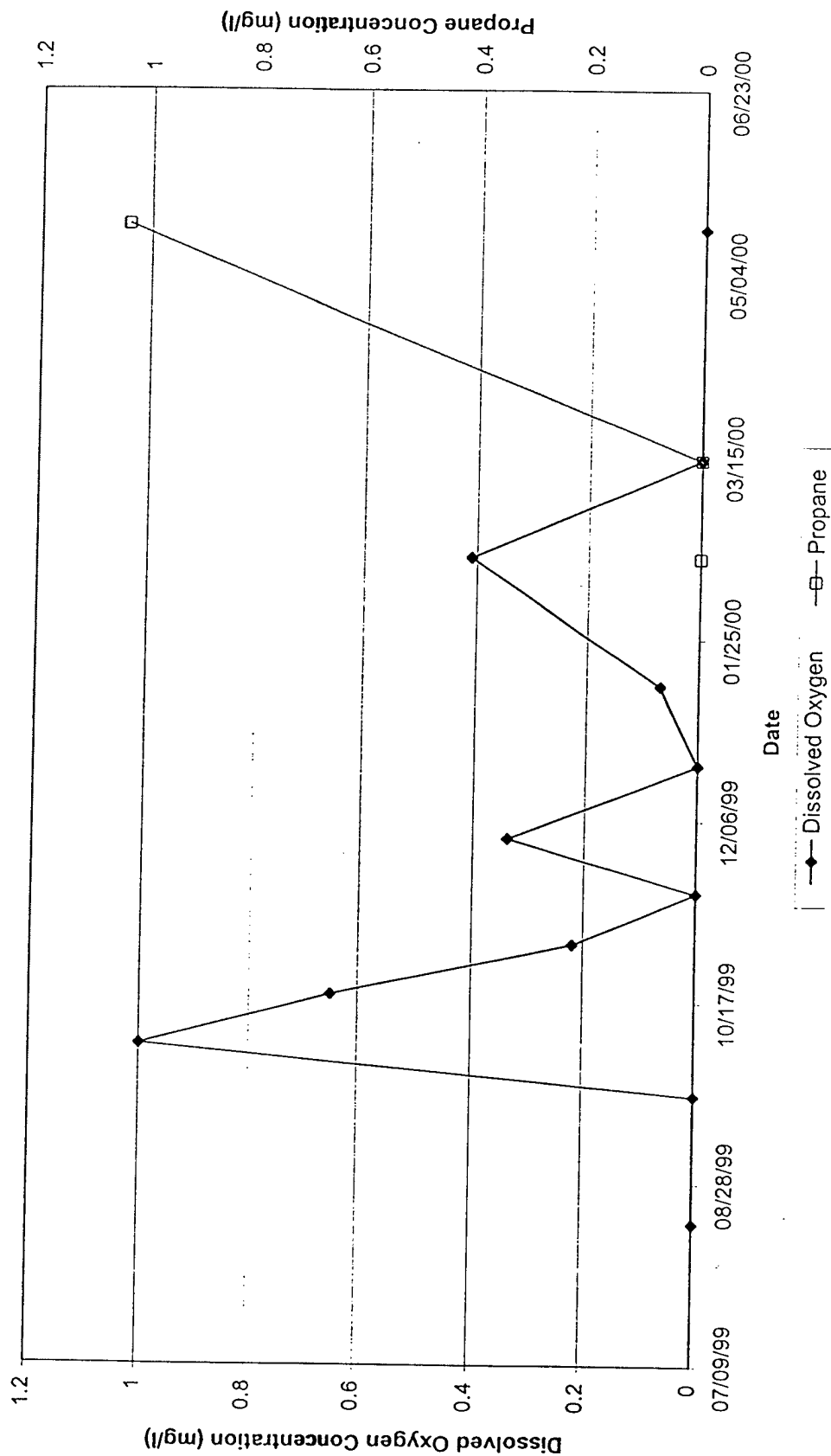


Figure 3.2.2.3  
MW3: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

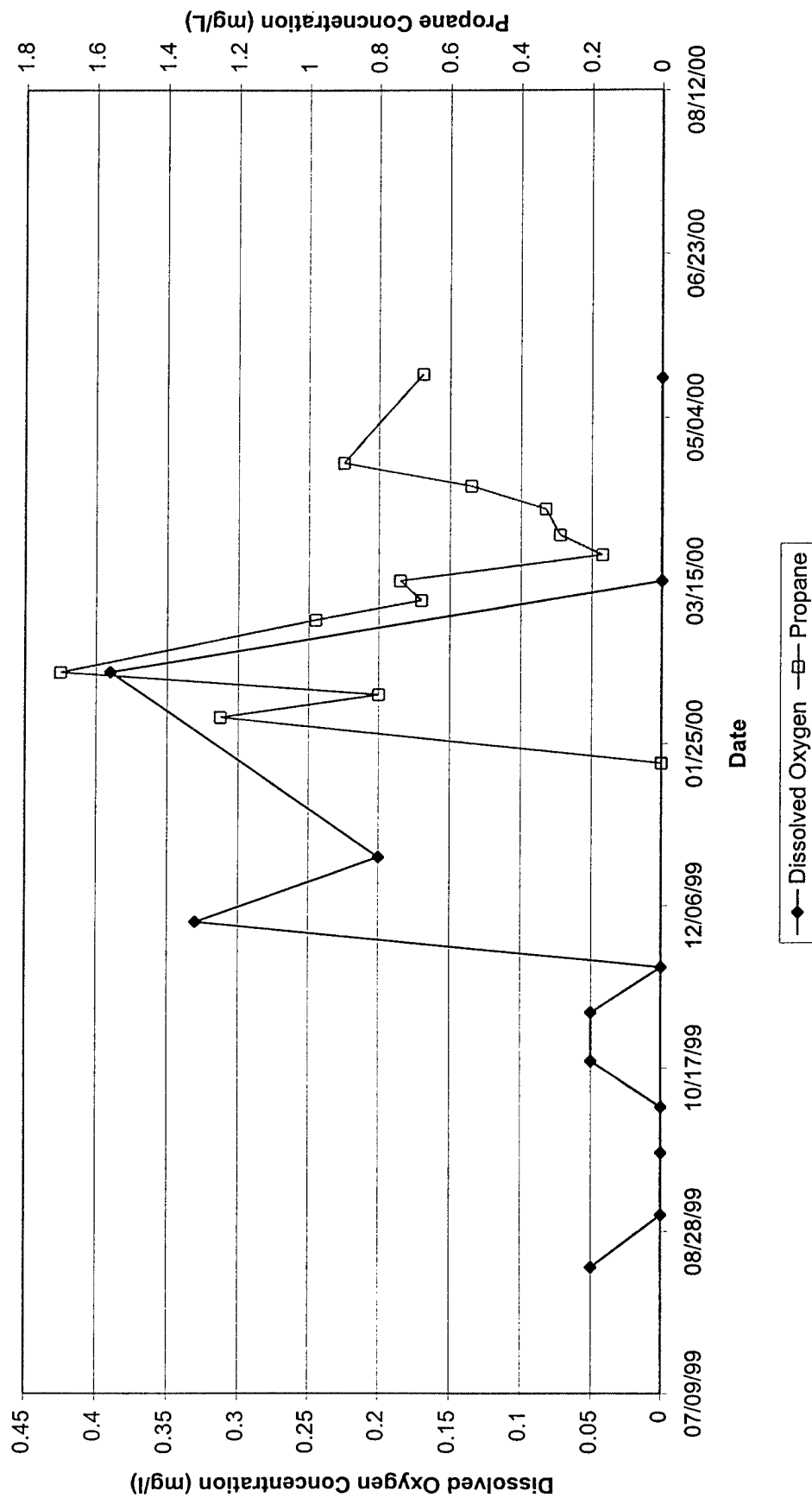


Figure 3.2.2.4  
MW4: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

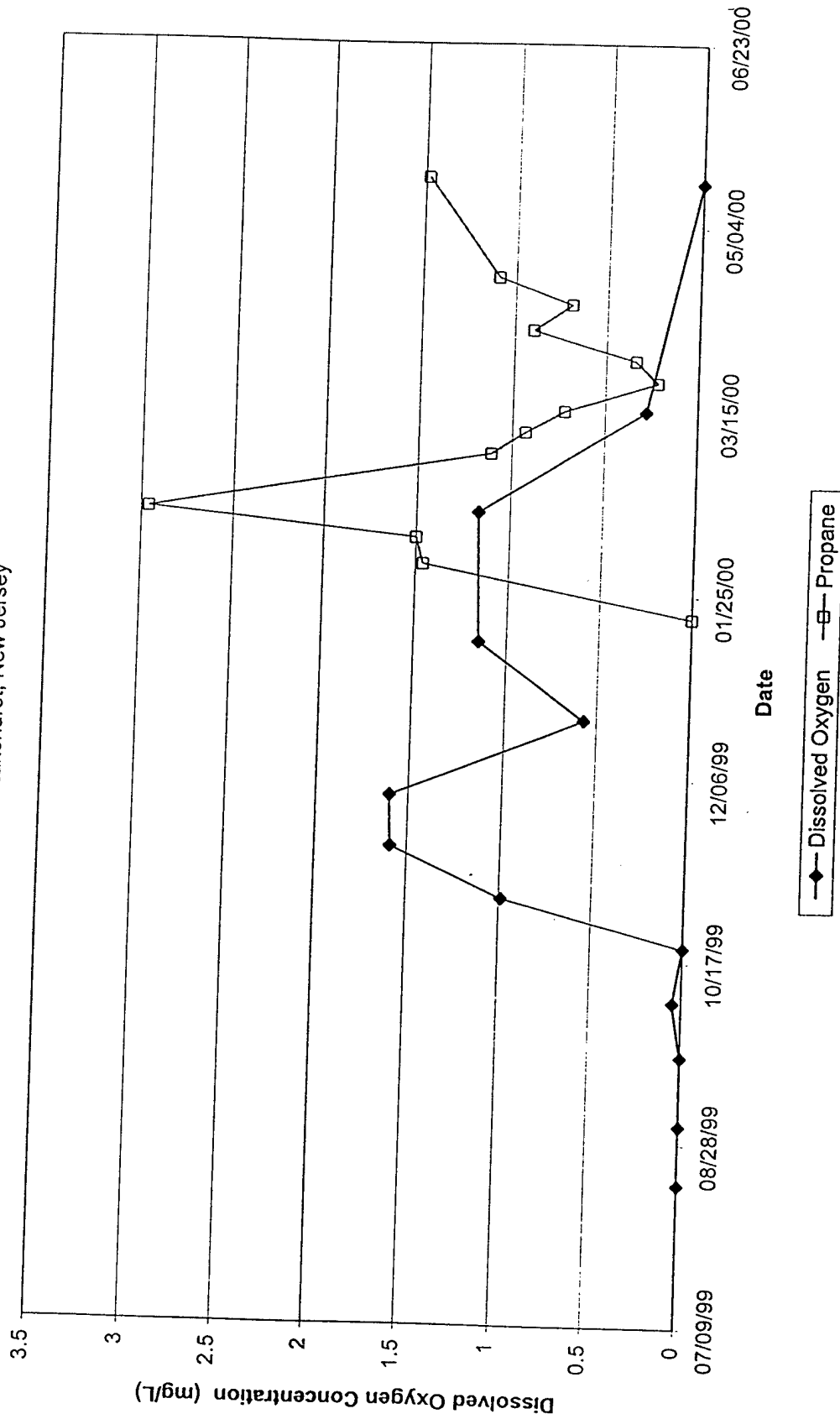


Figure 3.2.2.5  
MW5: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

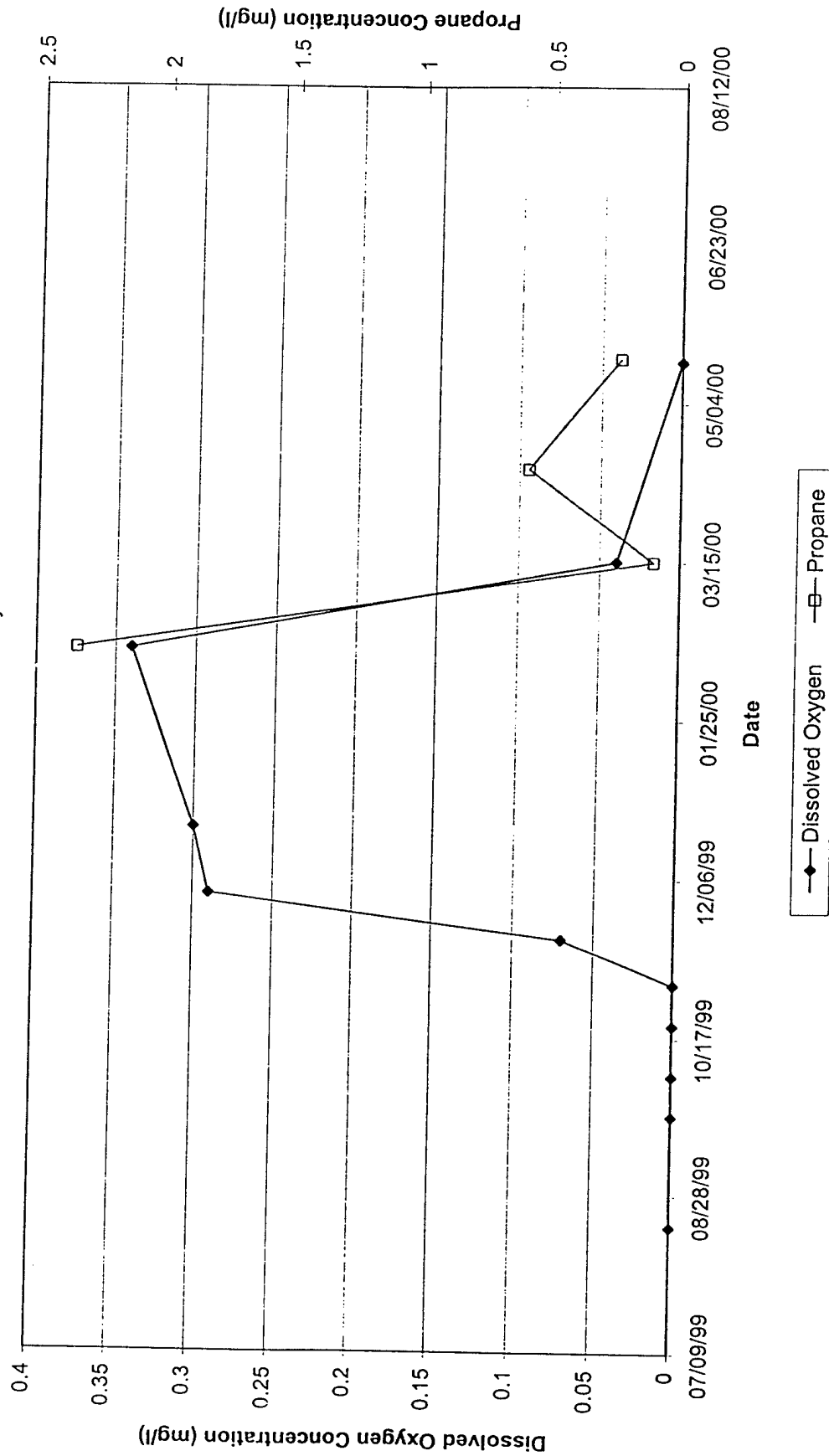


Figure 3.2.2.6  
MW6: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

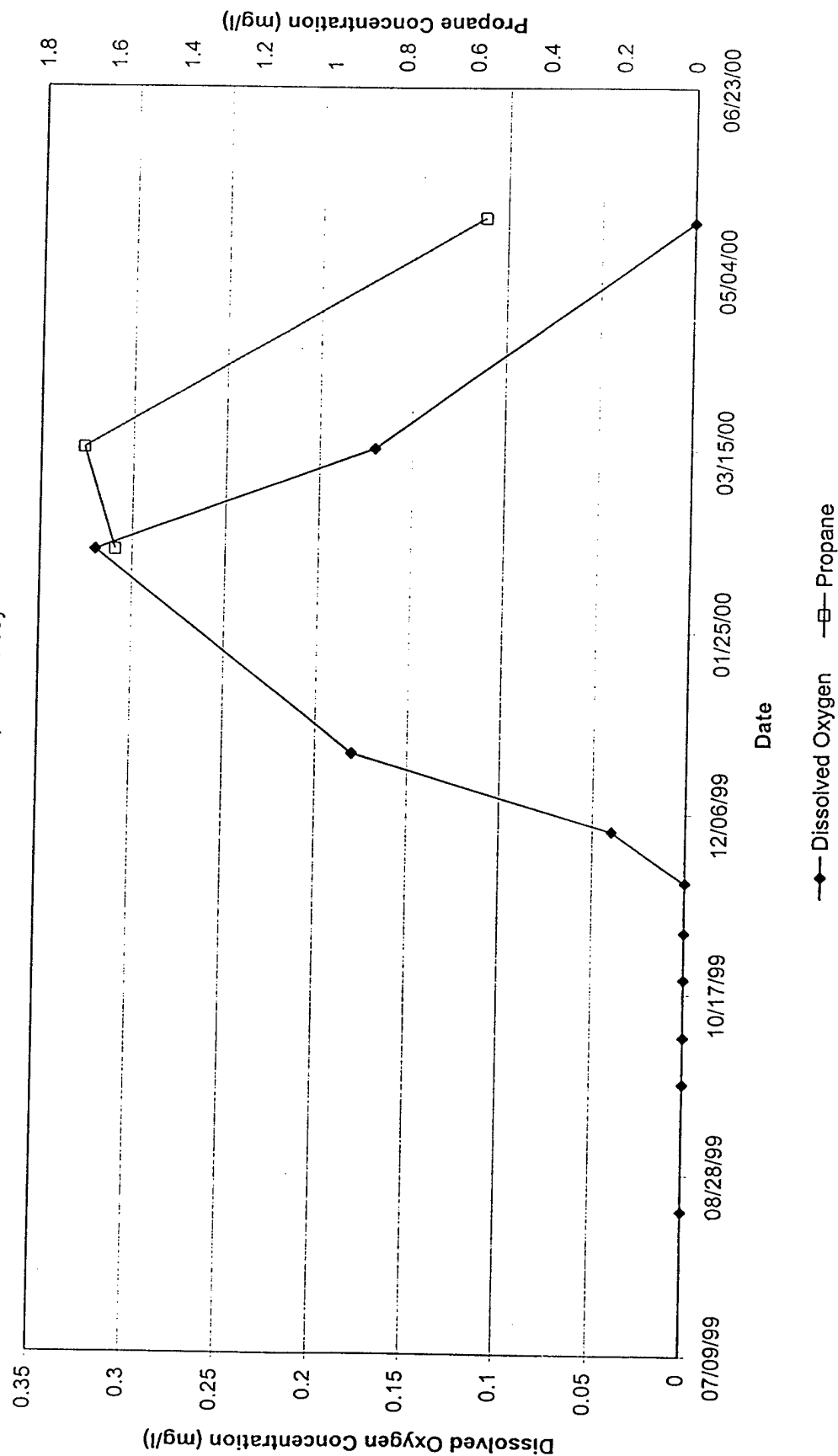




Figure 3.2.2.7  
 MW7: Dissolved Oxygen and Propane Concentrations vs. Time  
 Naval Air Engineering Station  
 Lakehurst, New Jersey

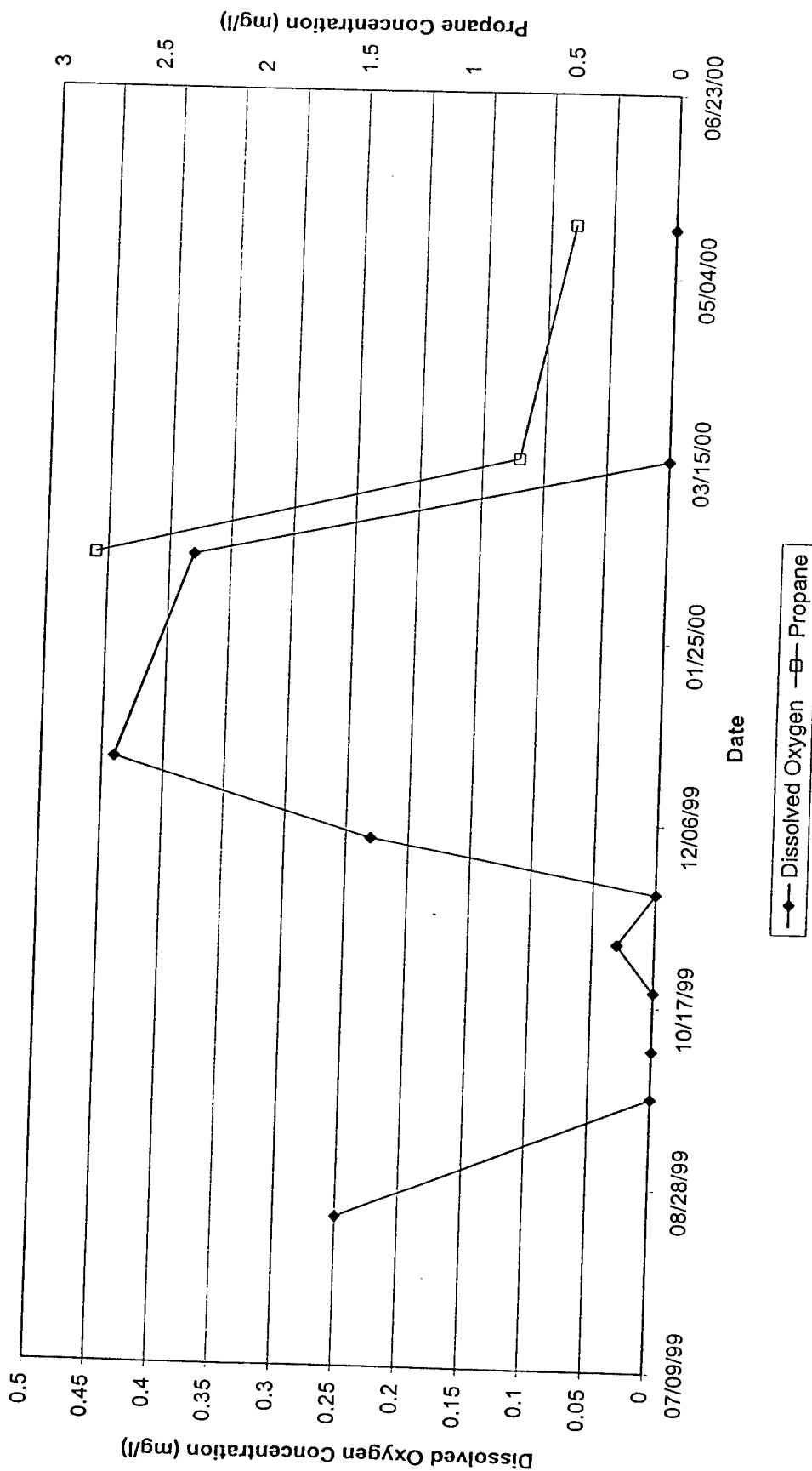


Figure 3.2.2.8  
 MW8: Dissolved Oxygen and Propane Concentrations vs. Time  
 Naval Air Engineering Station  
 Lakehurst, New Jersey

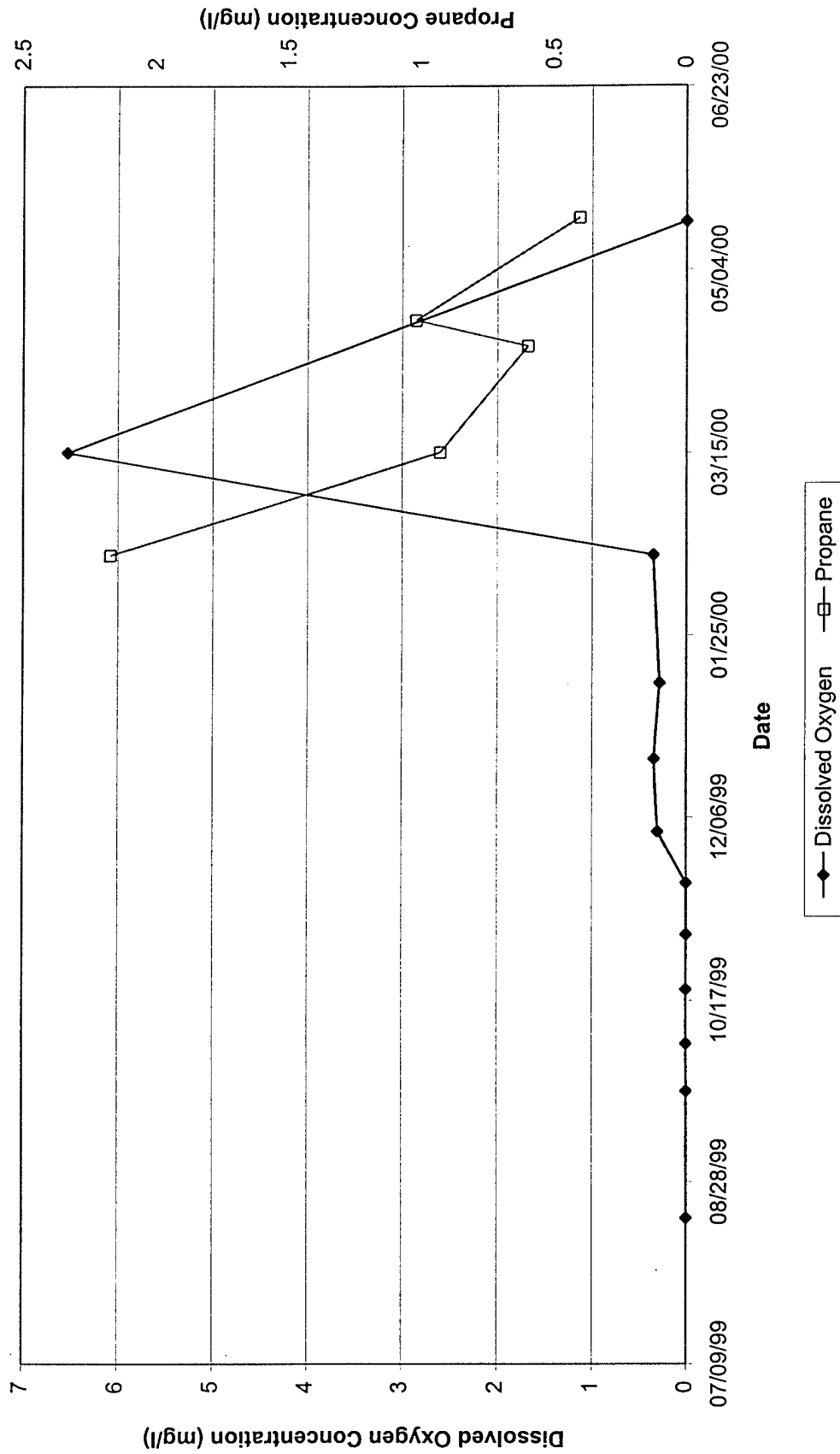


Figure 3.2.2.9  
Well LK: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

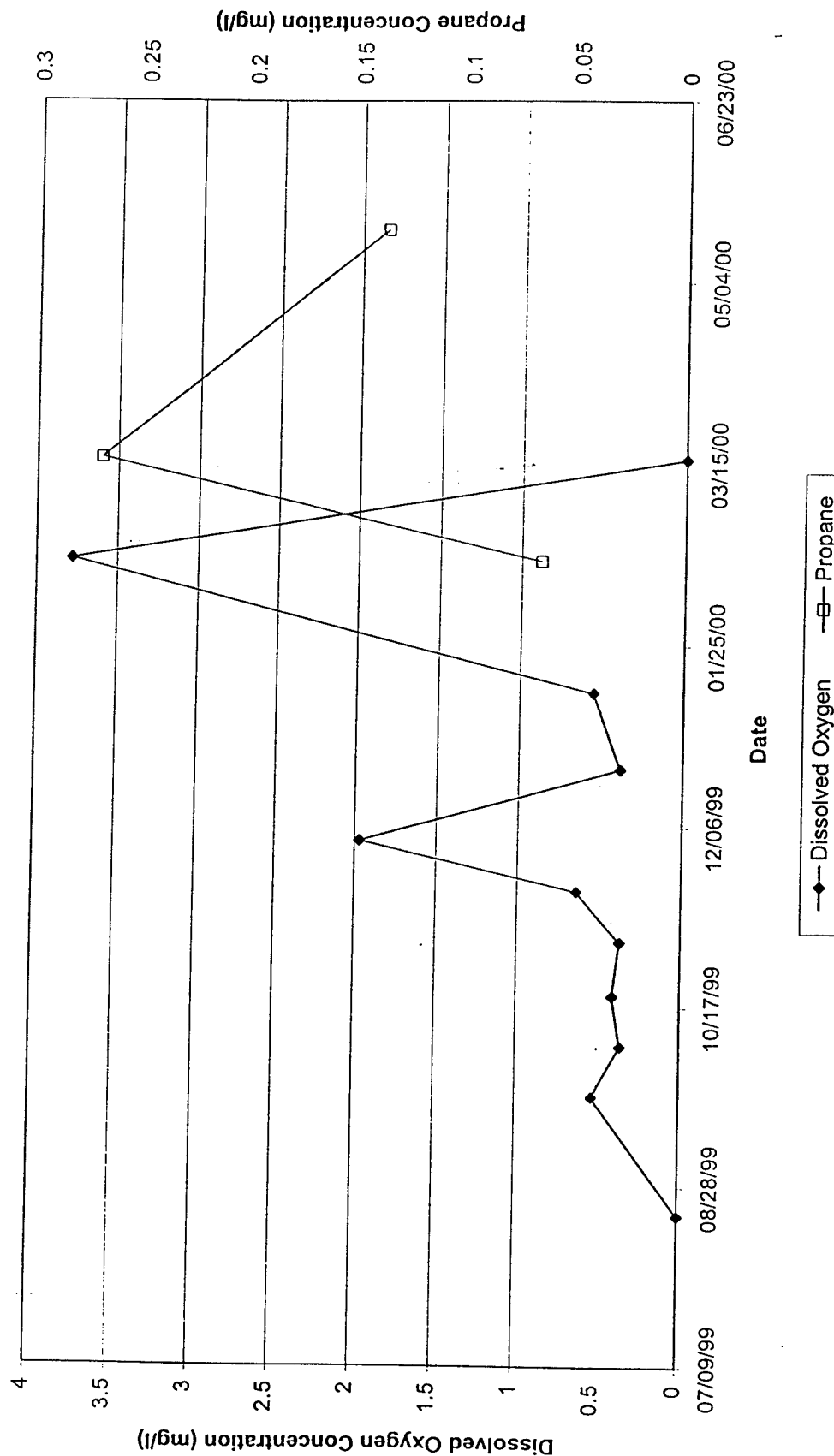


Figure 3.2.2.10  
RW 1: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

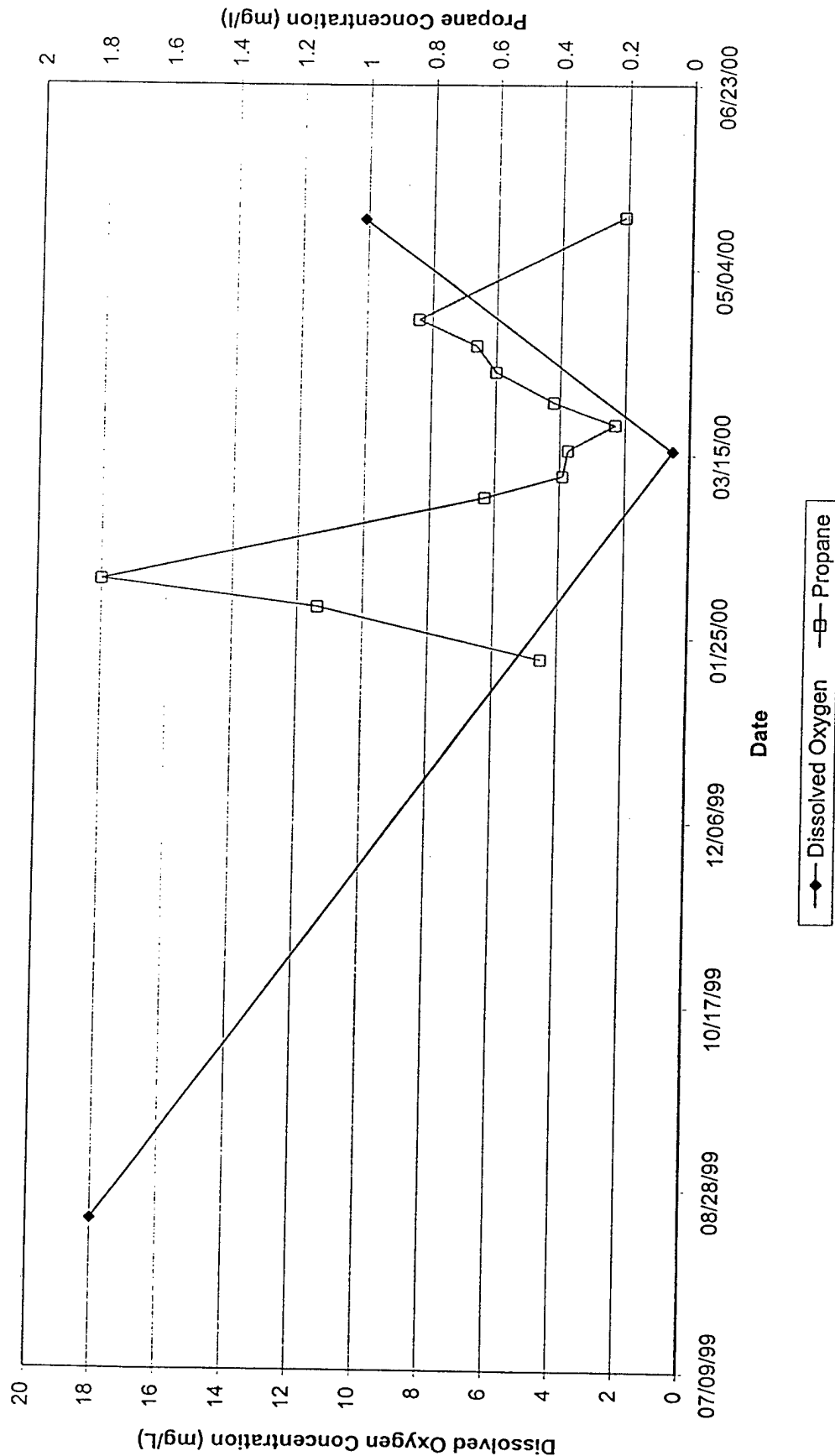


Figure 3.2.2.11  
OW1: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

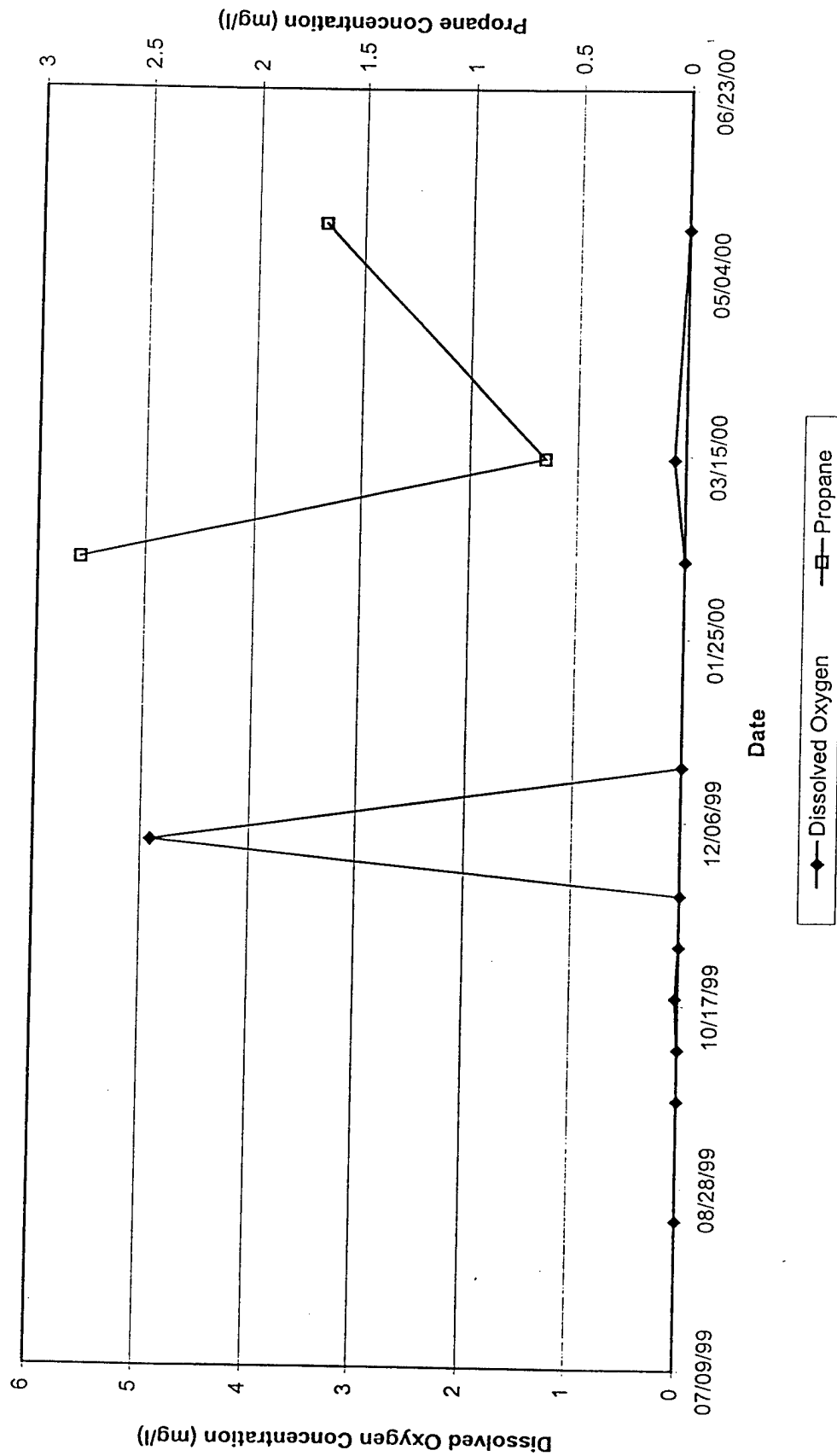


Figure 3.2.2.12  
OW5: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

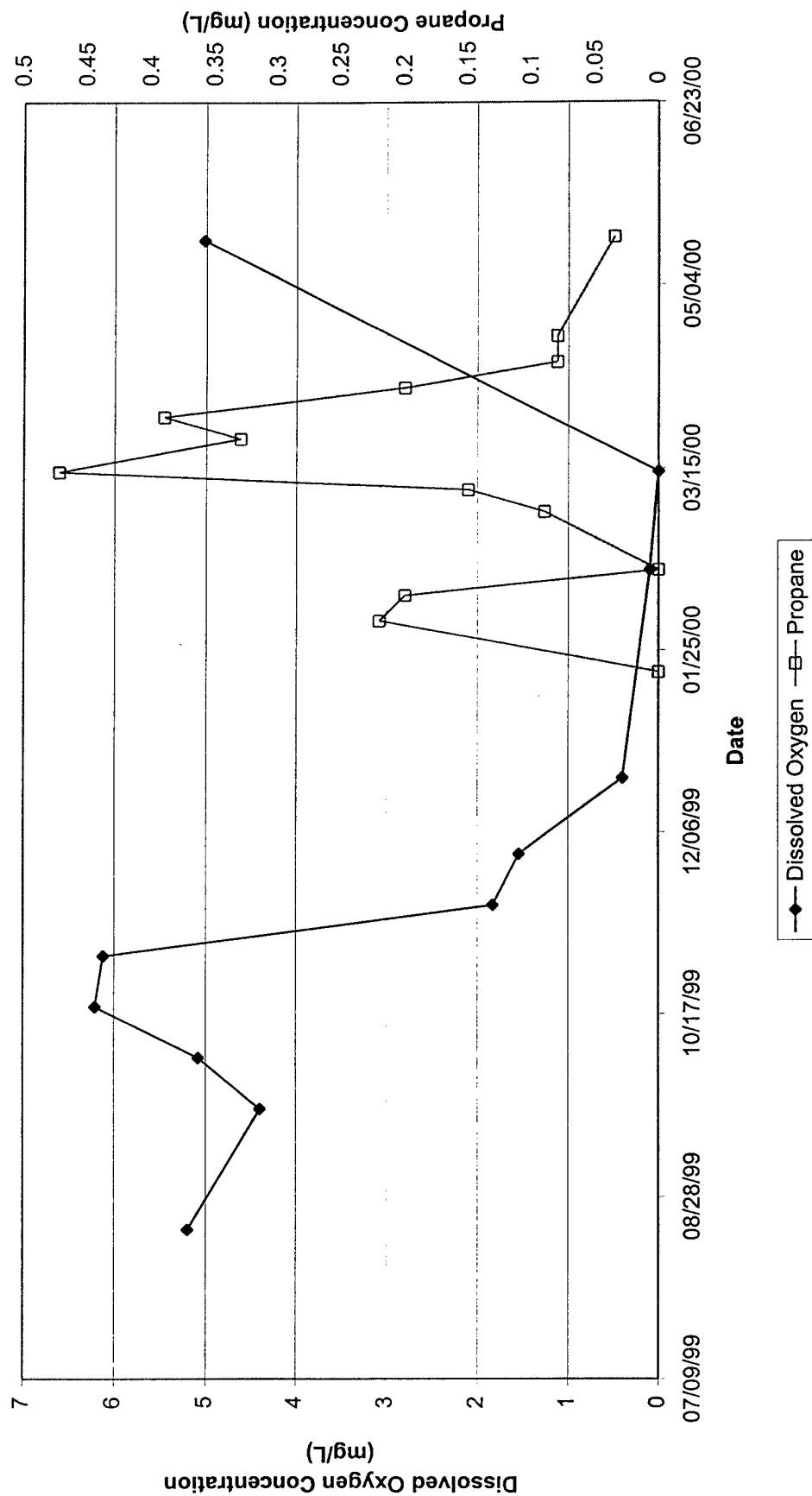


Figure 3.2.2.13  
OW6: Dissolved Oxygen and Propane Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

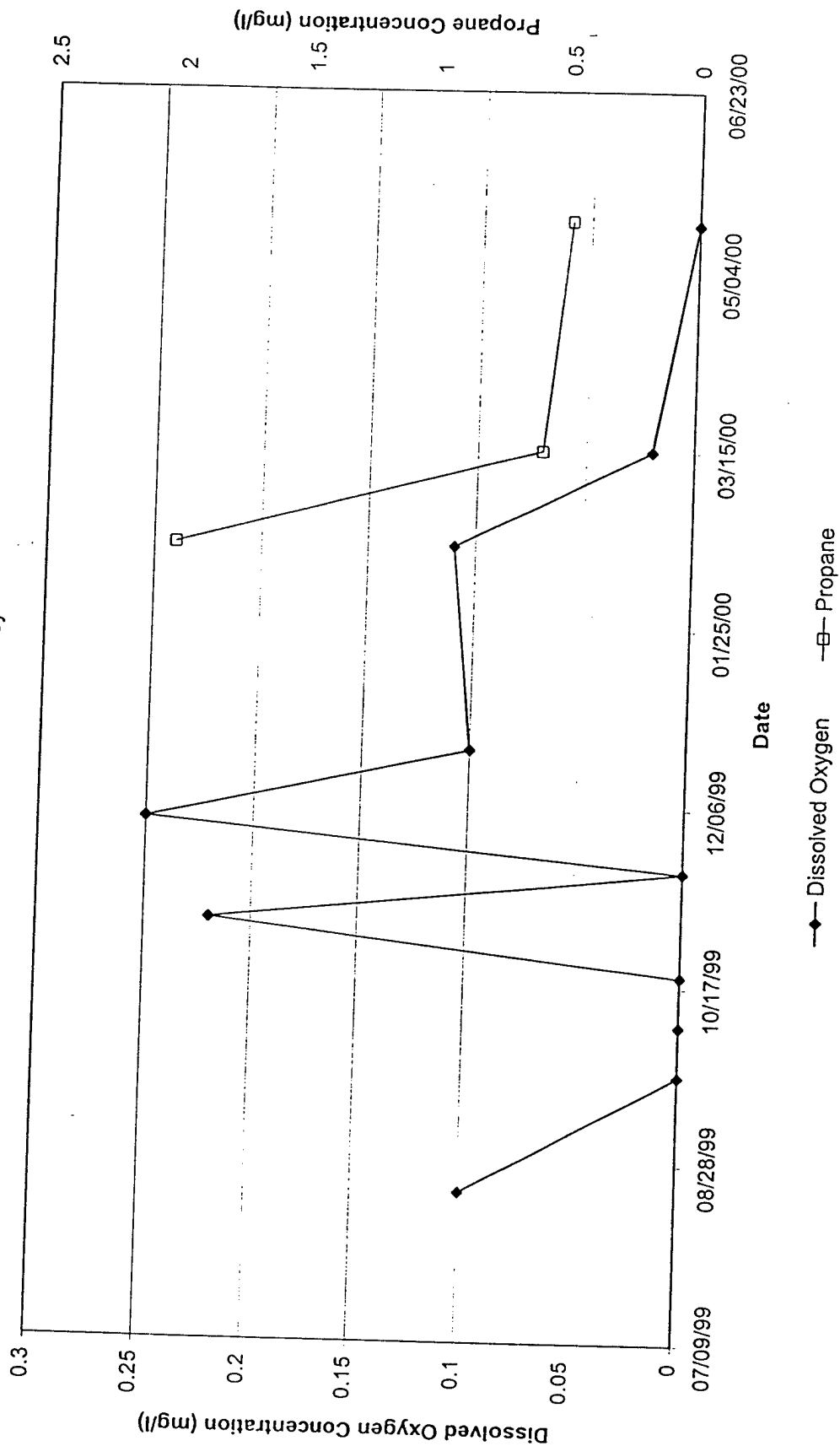


Figure 3.2.6.1  
MW1: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

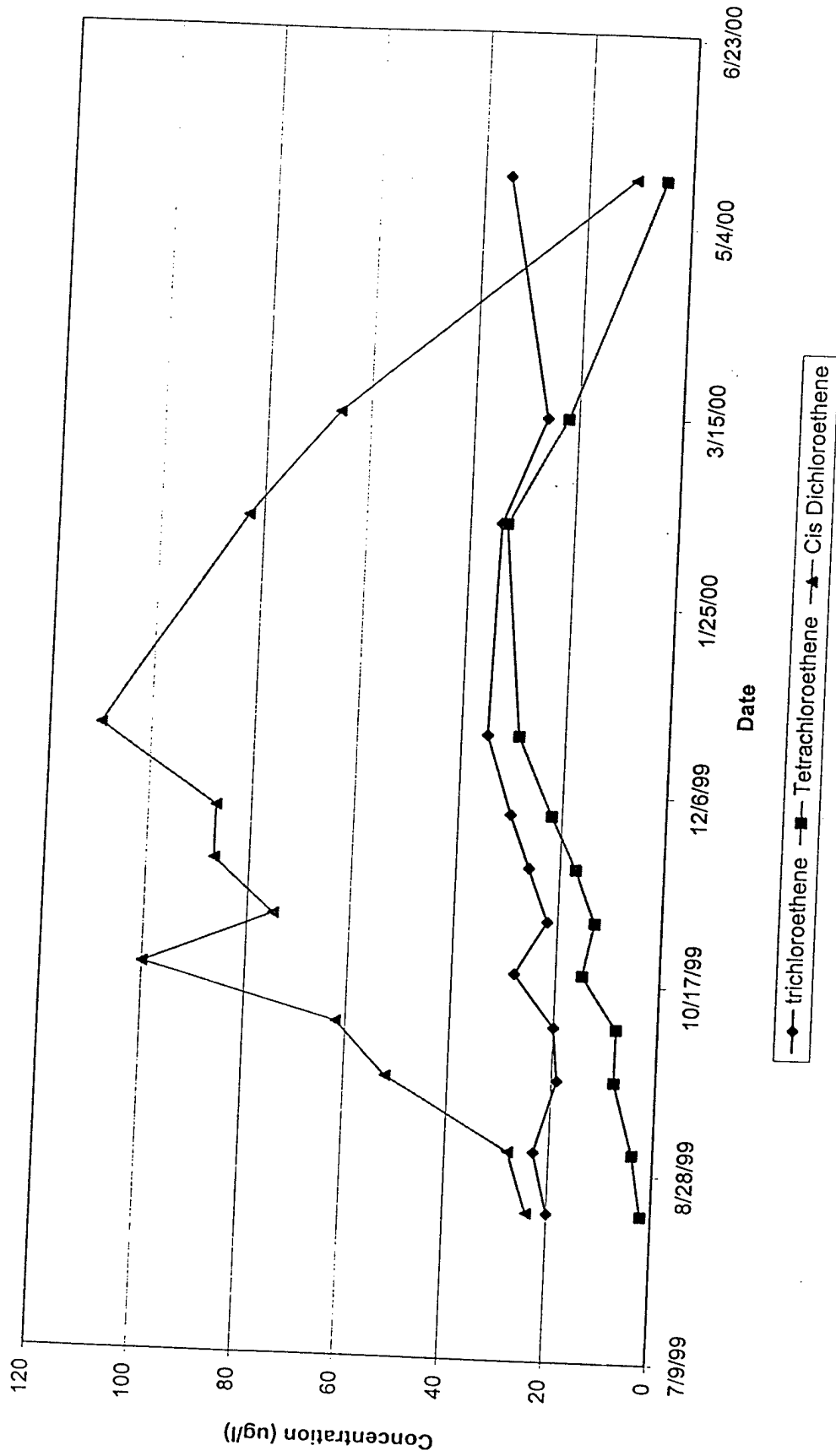




Figure 3.2.6.2  
MW2: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

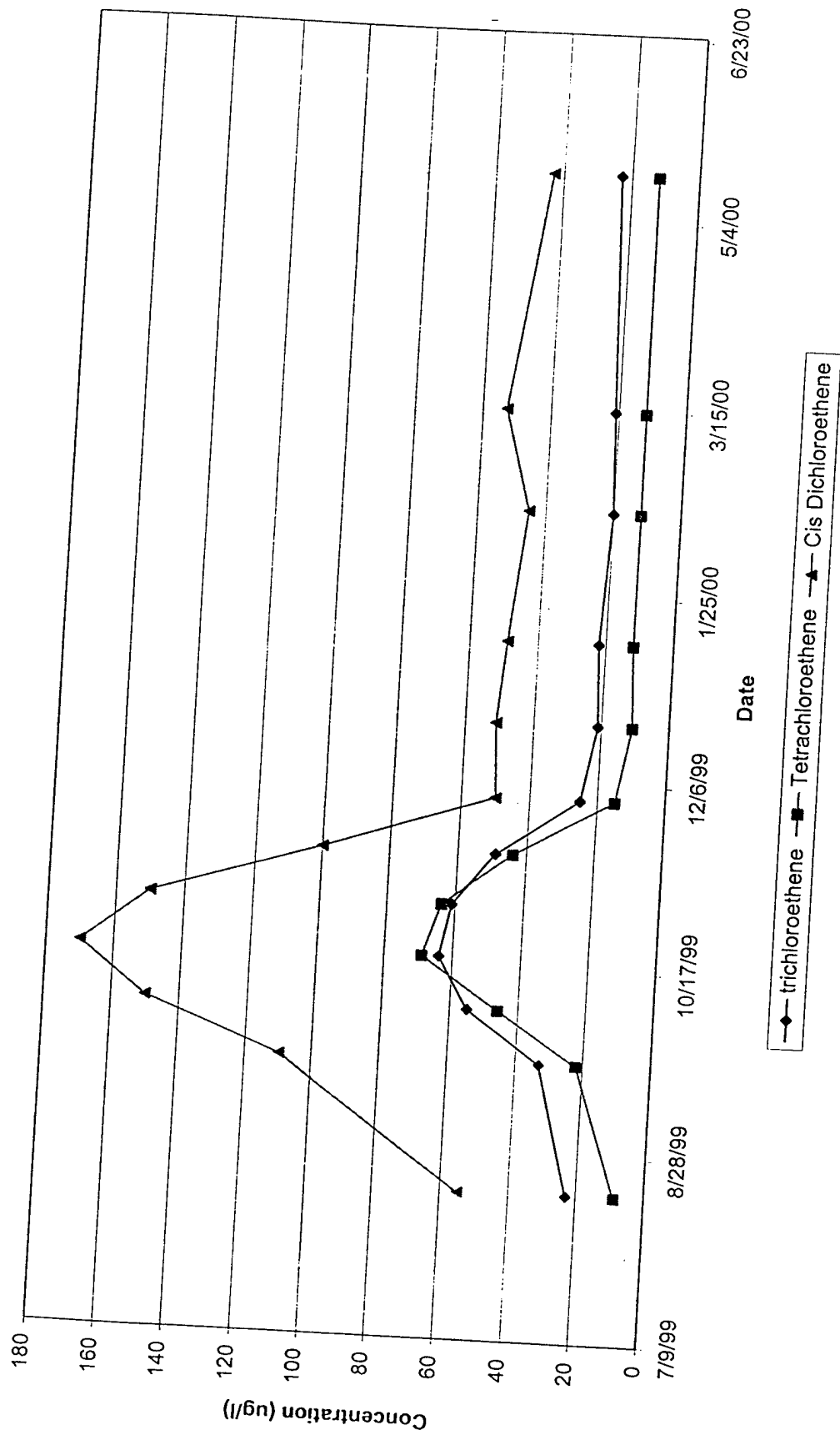


Figure 3.2.6.3  
MW3: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

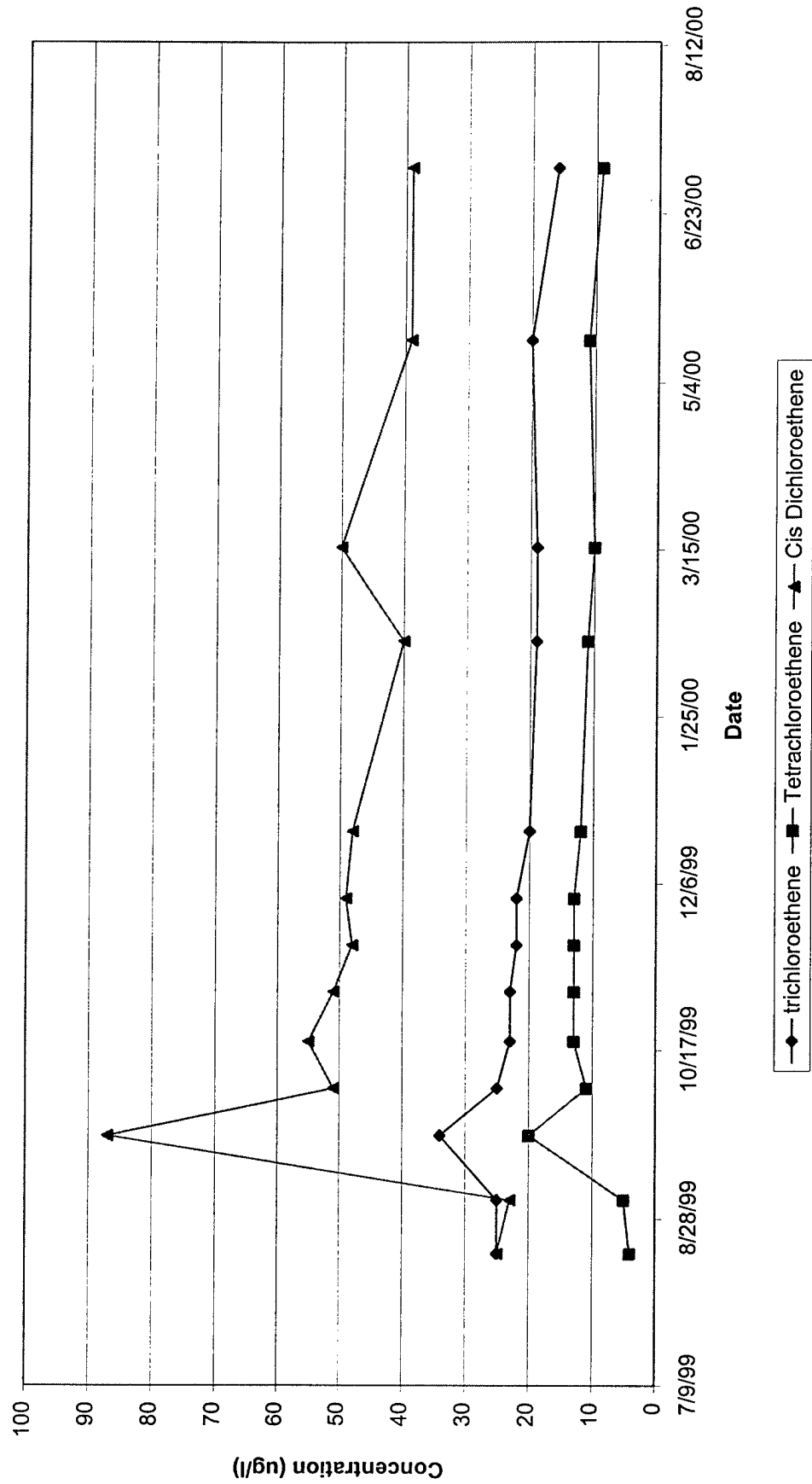


Figure 3.2.6.4  
MW4: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

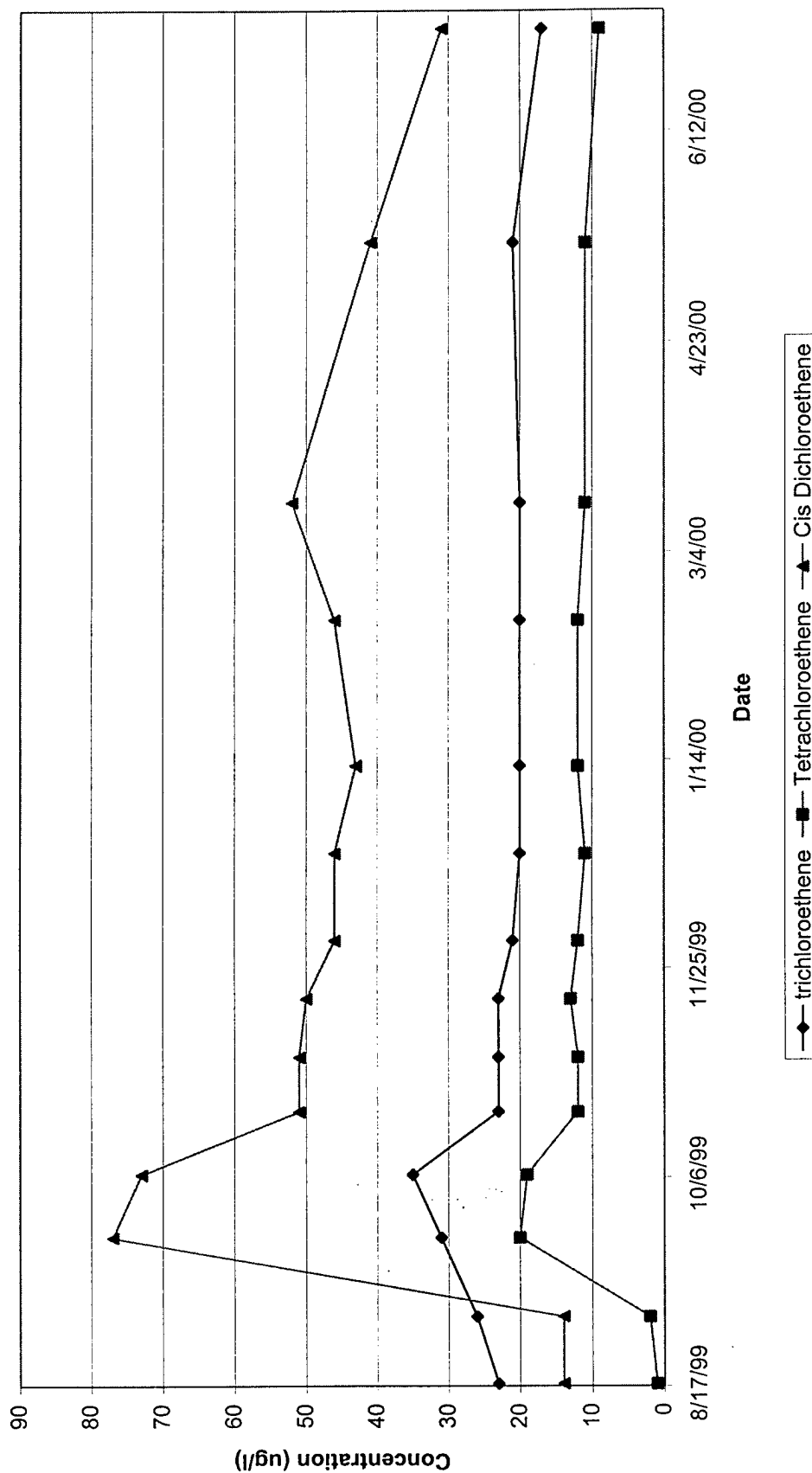


Figure 3.2.6.5  
MW5: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

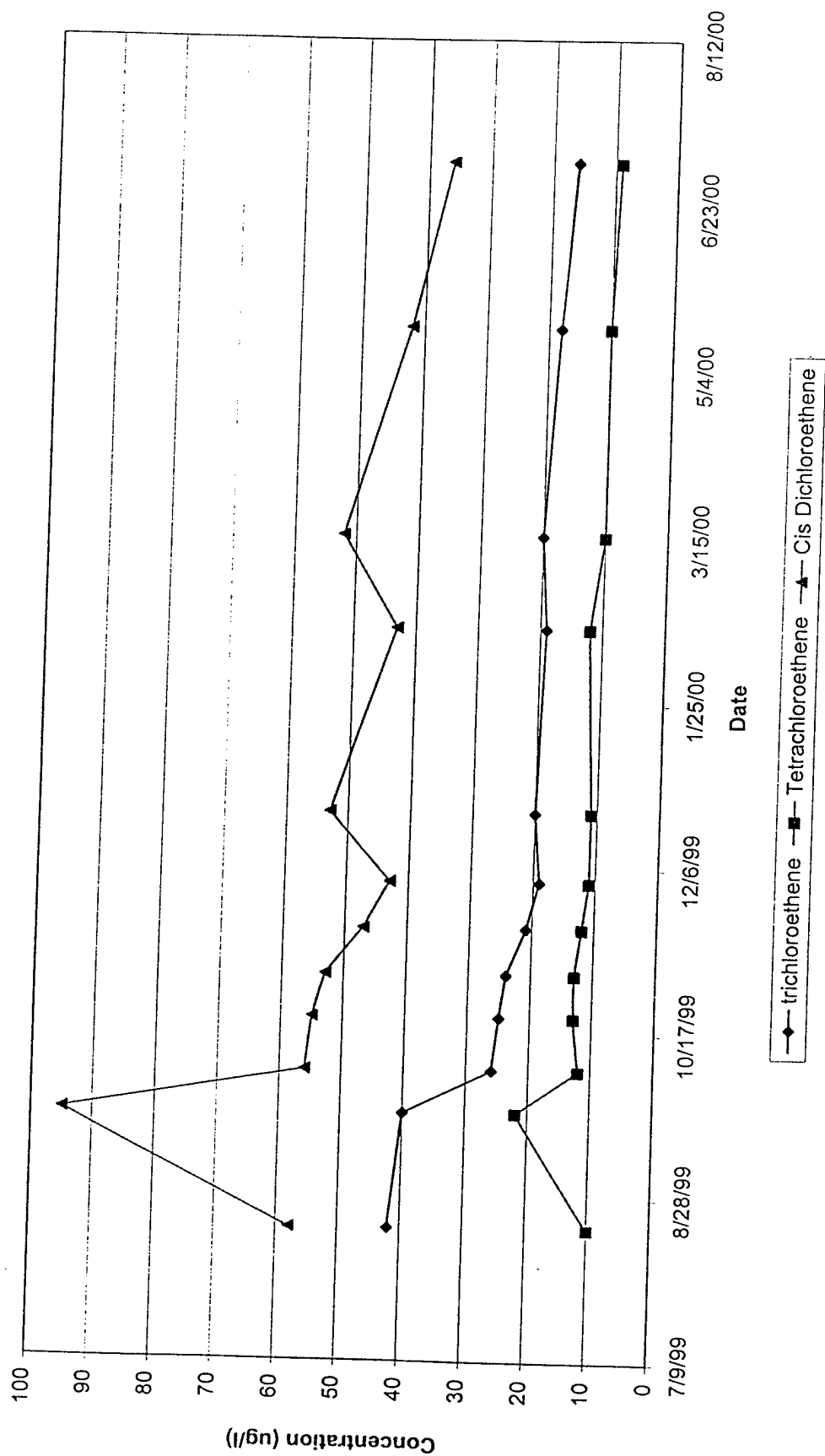


Figure 3.2.6.6  
MW6: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

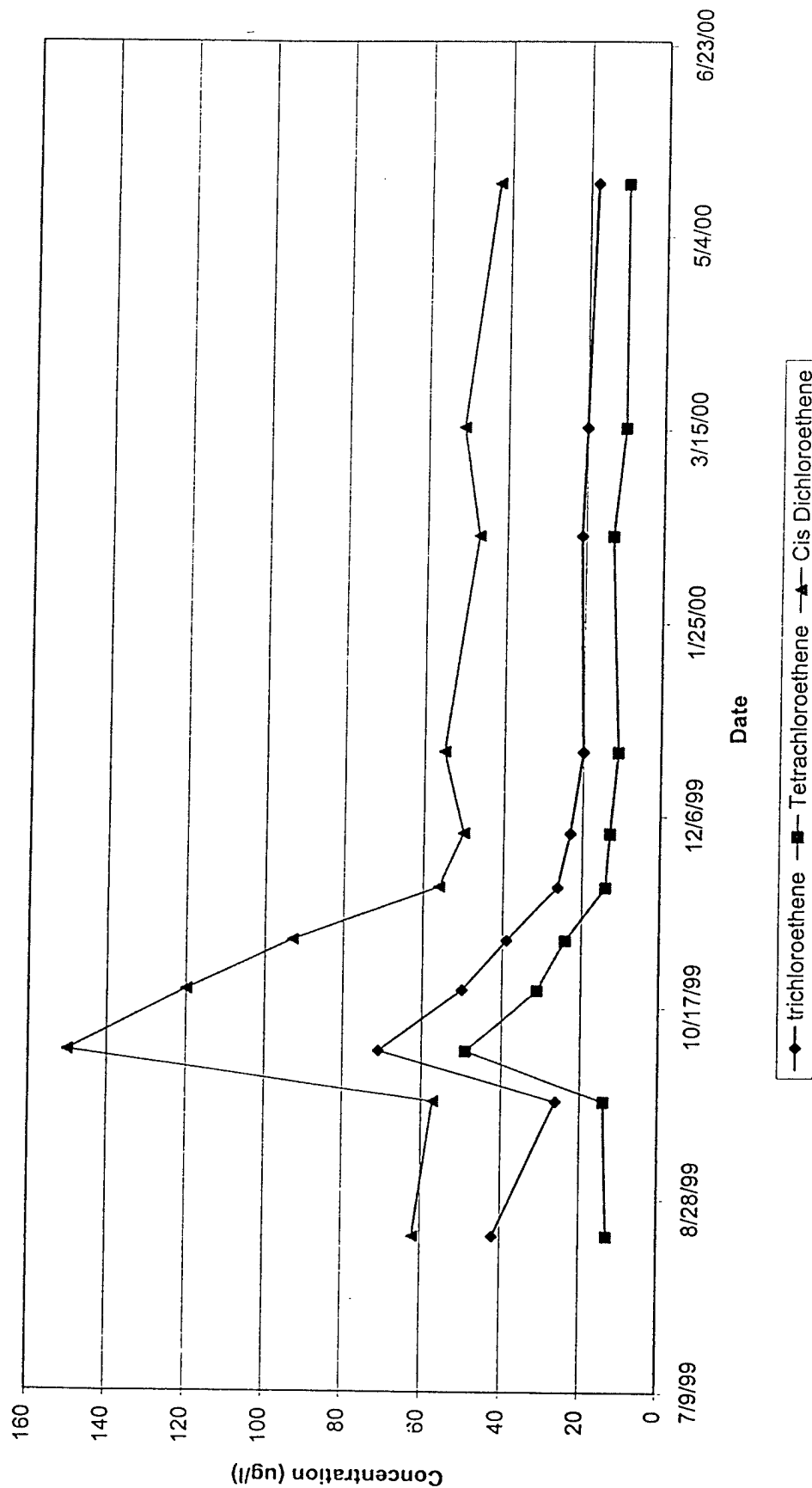


Figure 3.2.6.7  
MW7: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

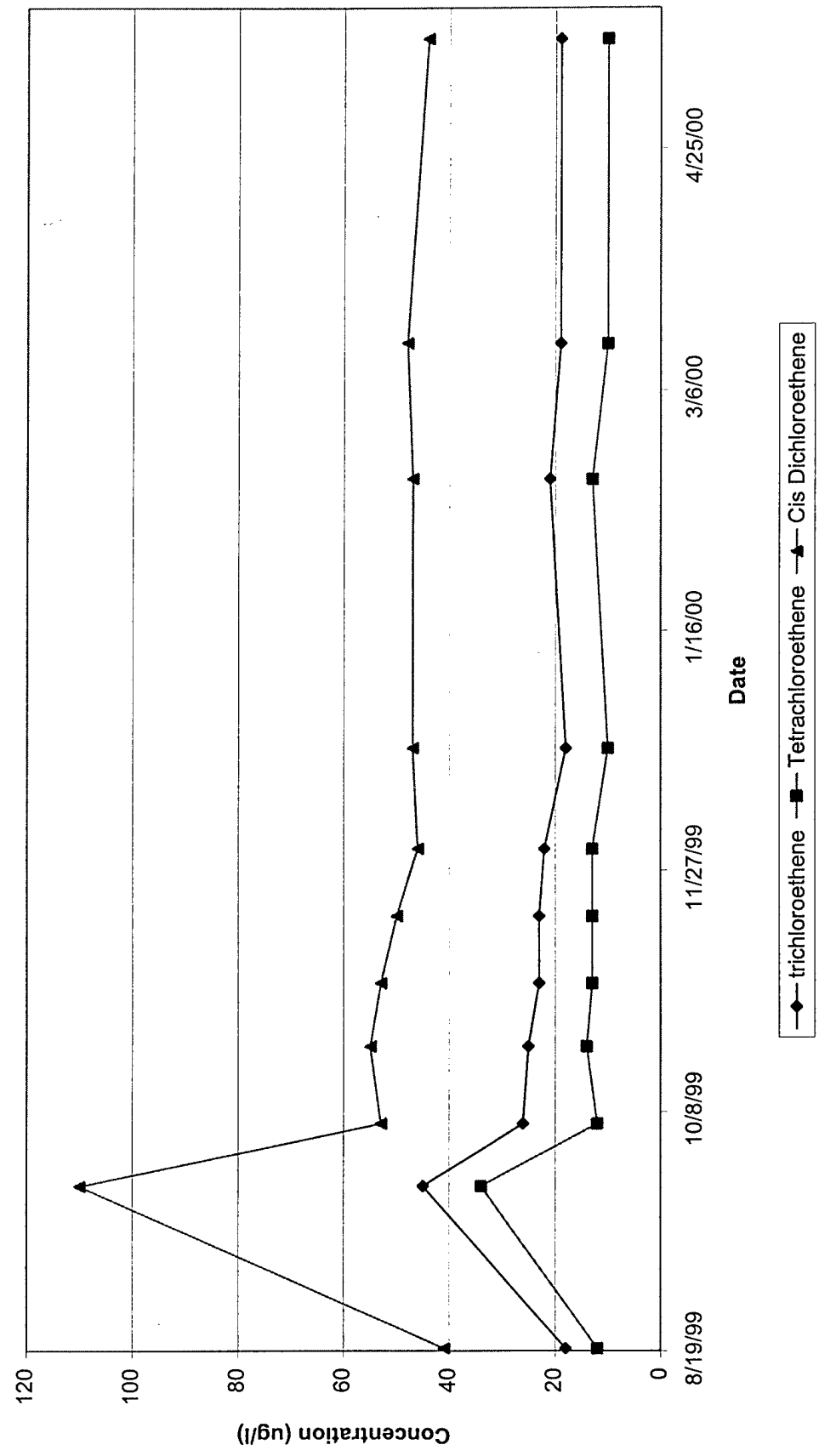


Figure 3.2.6.8  
MW8: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

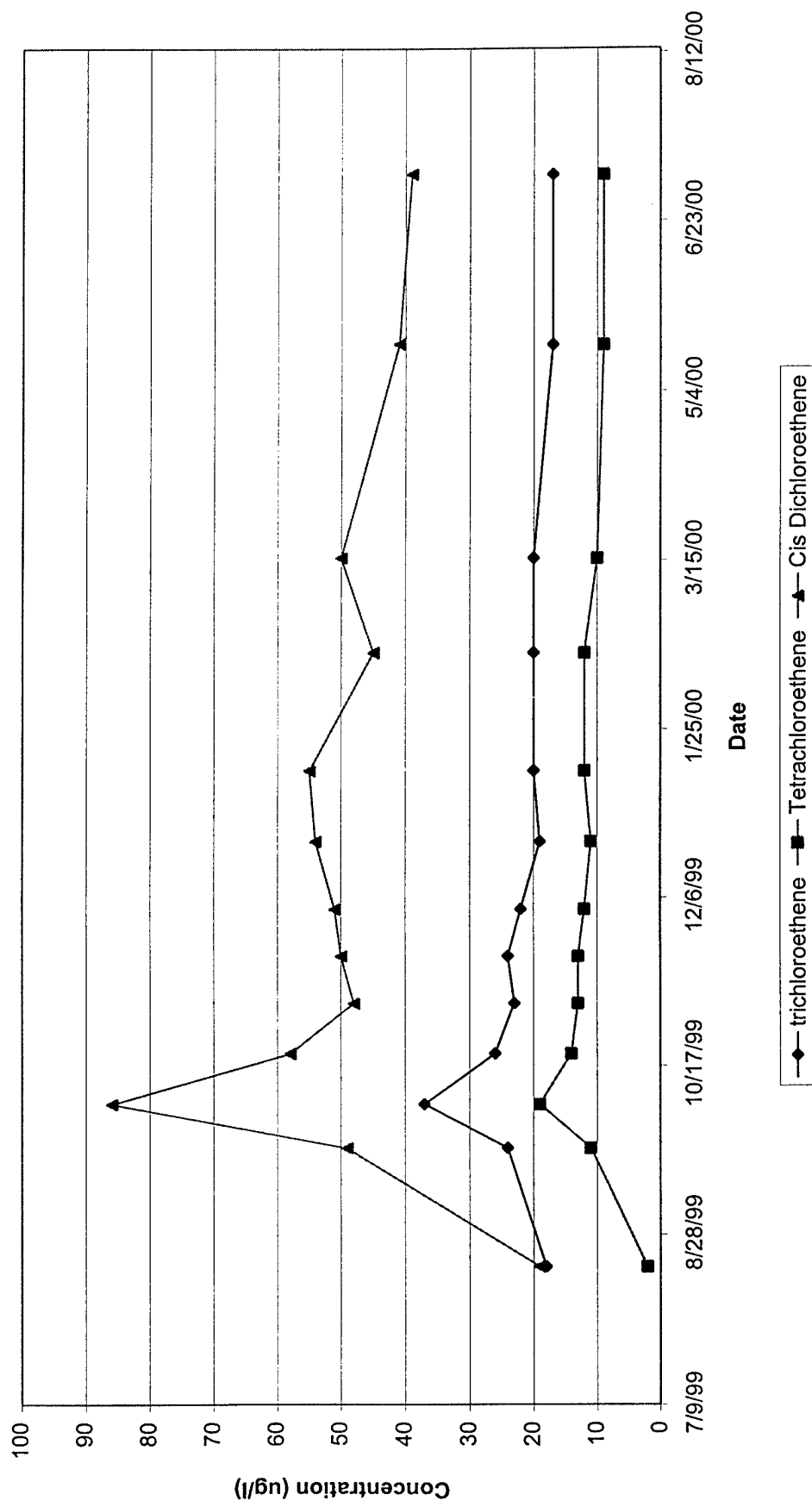


Figure 3.2.6.9  
Well LK: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

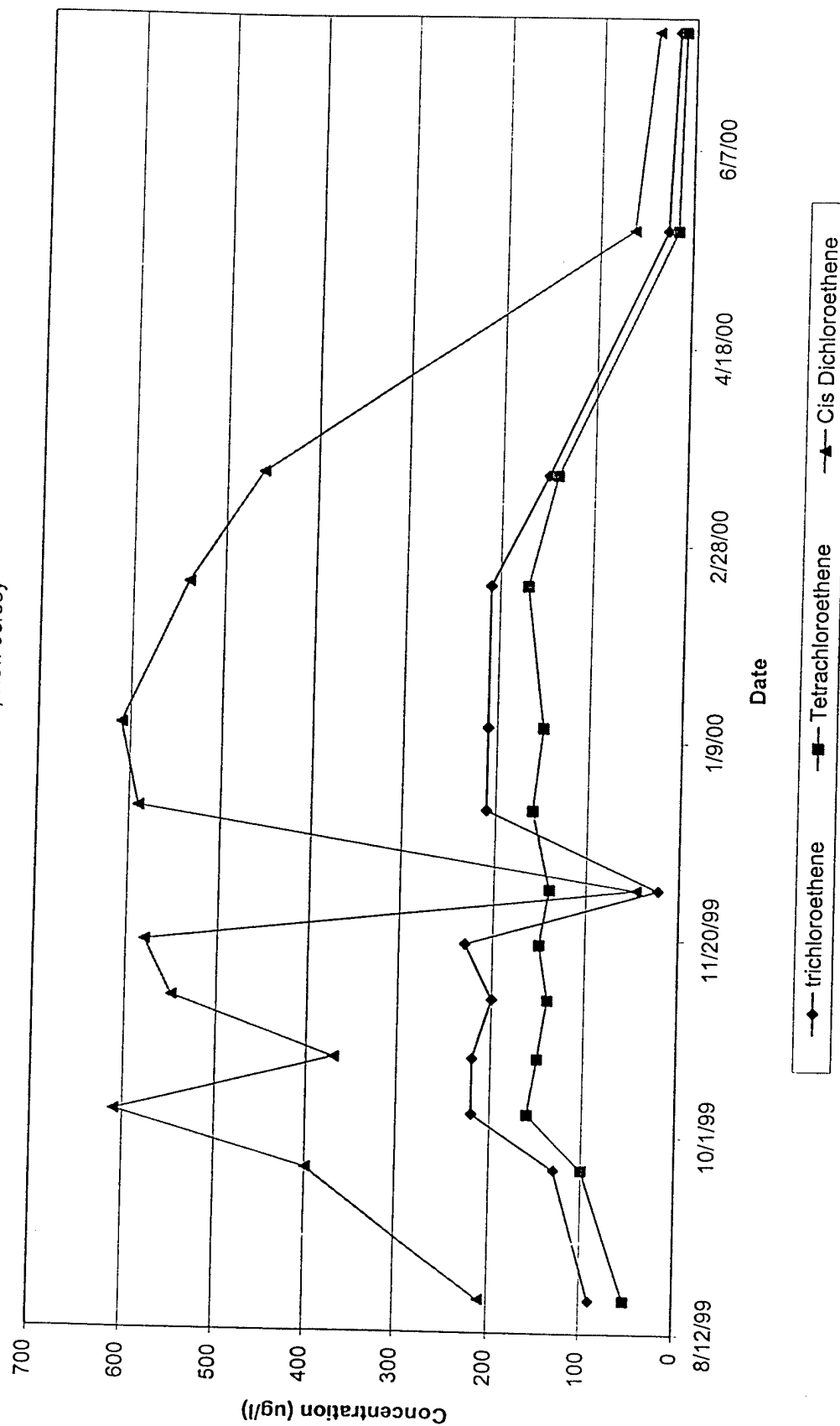




Figure 3.2.6.10  
RW1: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

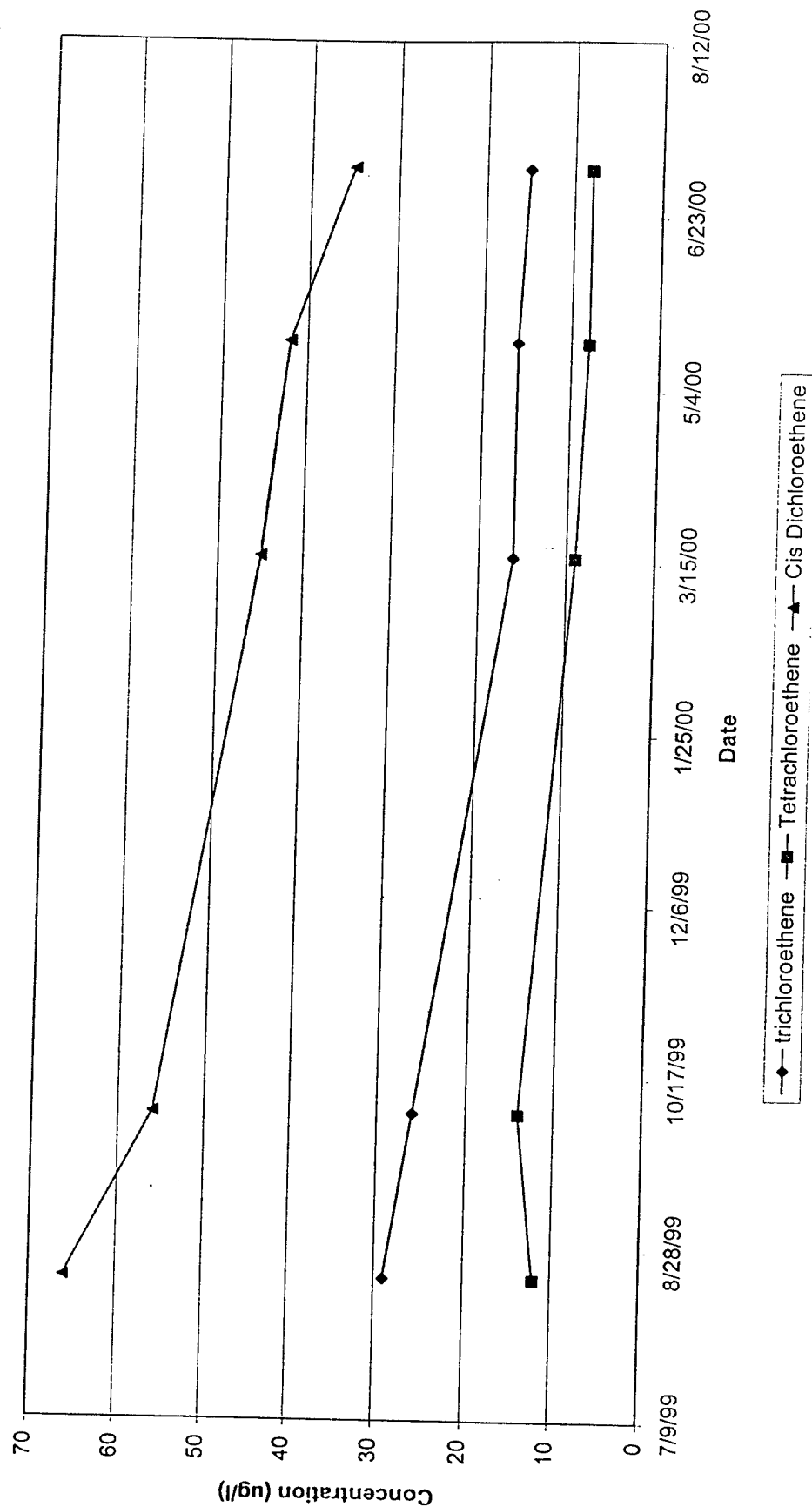


Figure 3.2.6.11  
OW1: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

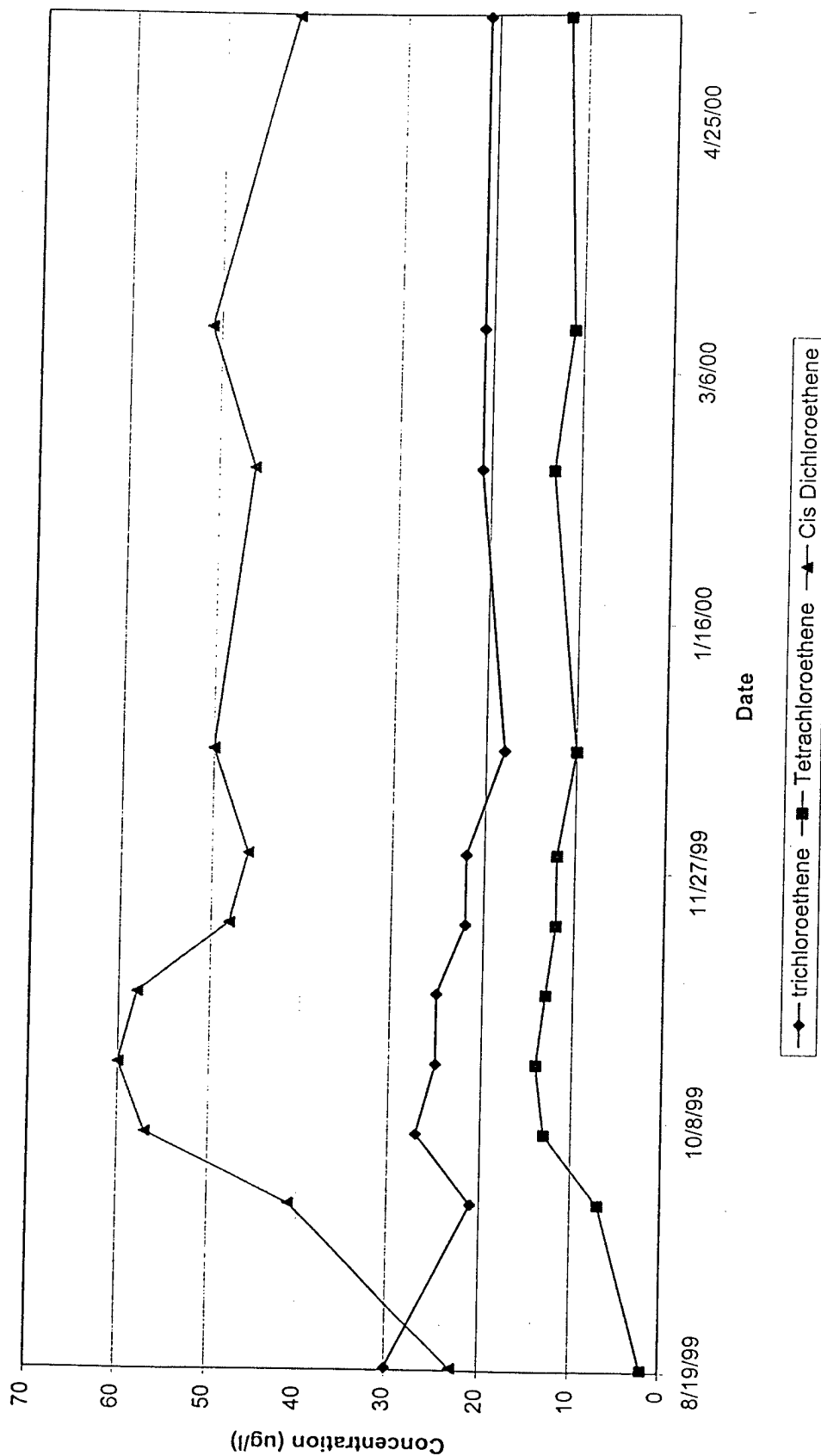


Figure 3.2.6.12  
OW5: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

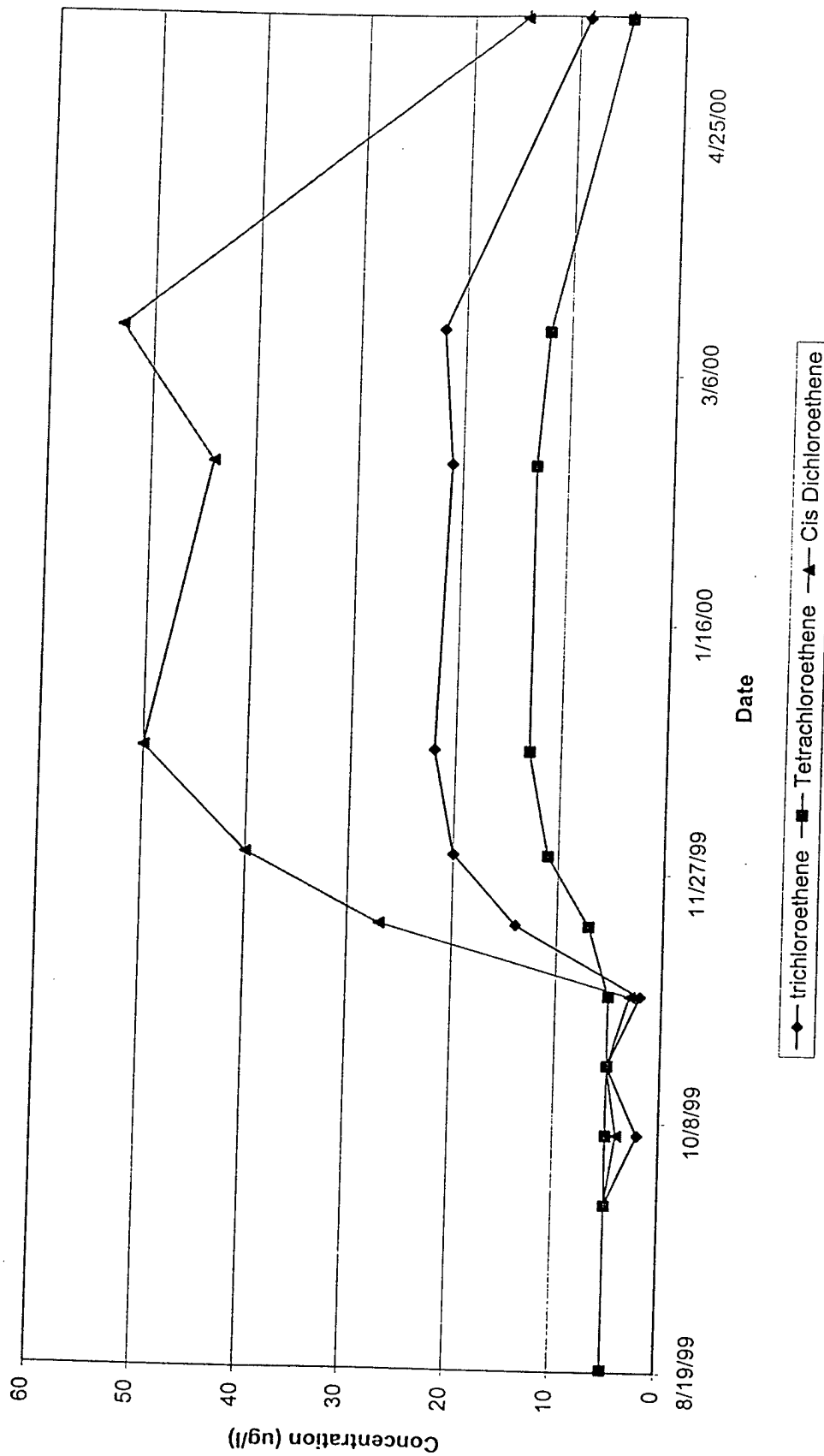


Figure 3.2.6.13  
OW6: Selected VOC Concentrations vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

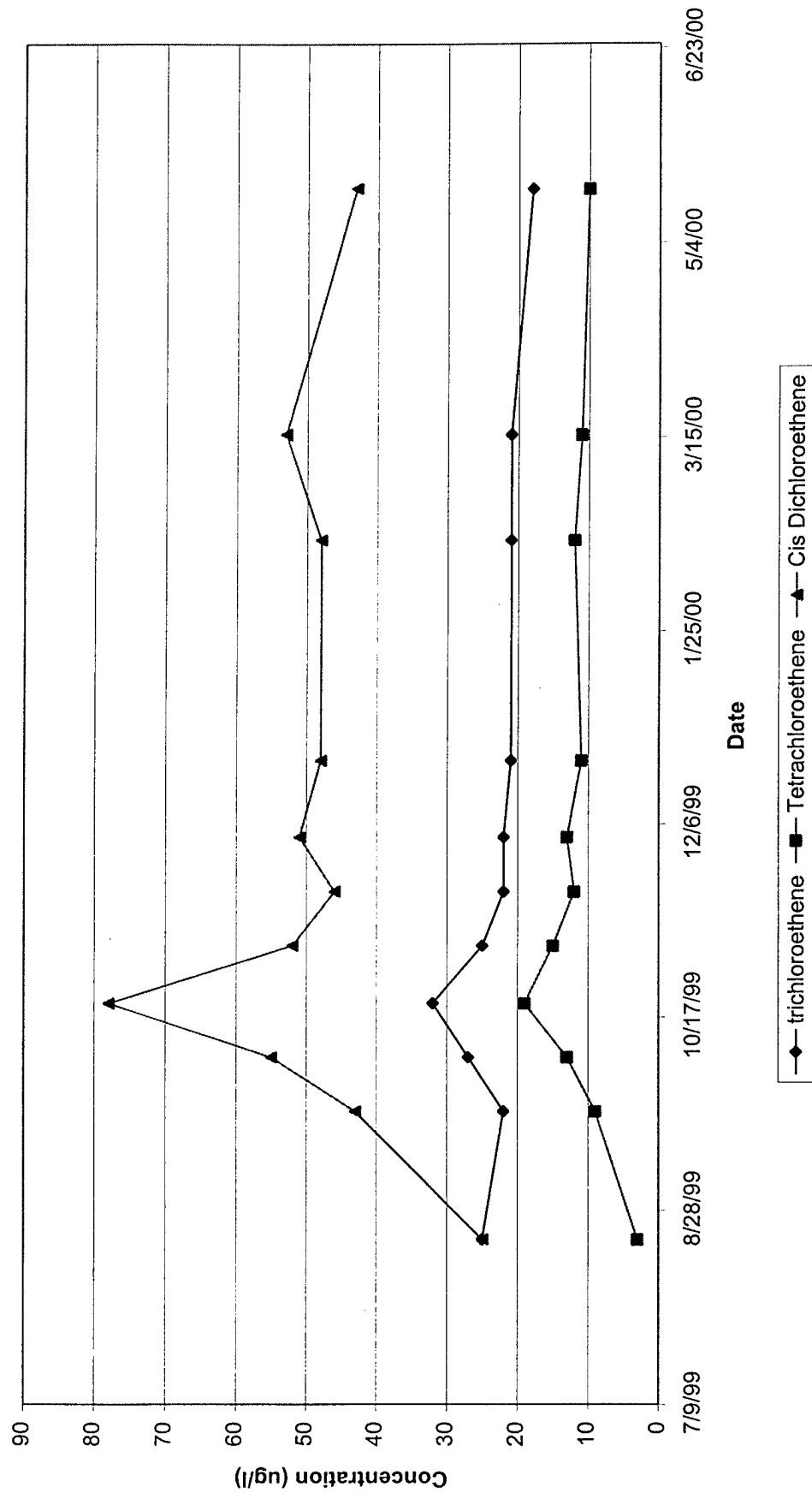


Figure 3.2.6.14  
 MW1: Selected VOC Concentrations Relative to PCE vs. Time

Naval Air Engineering Station  
 Lakehurst, New Jersey

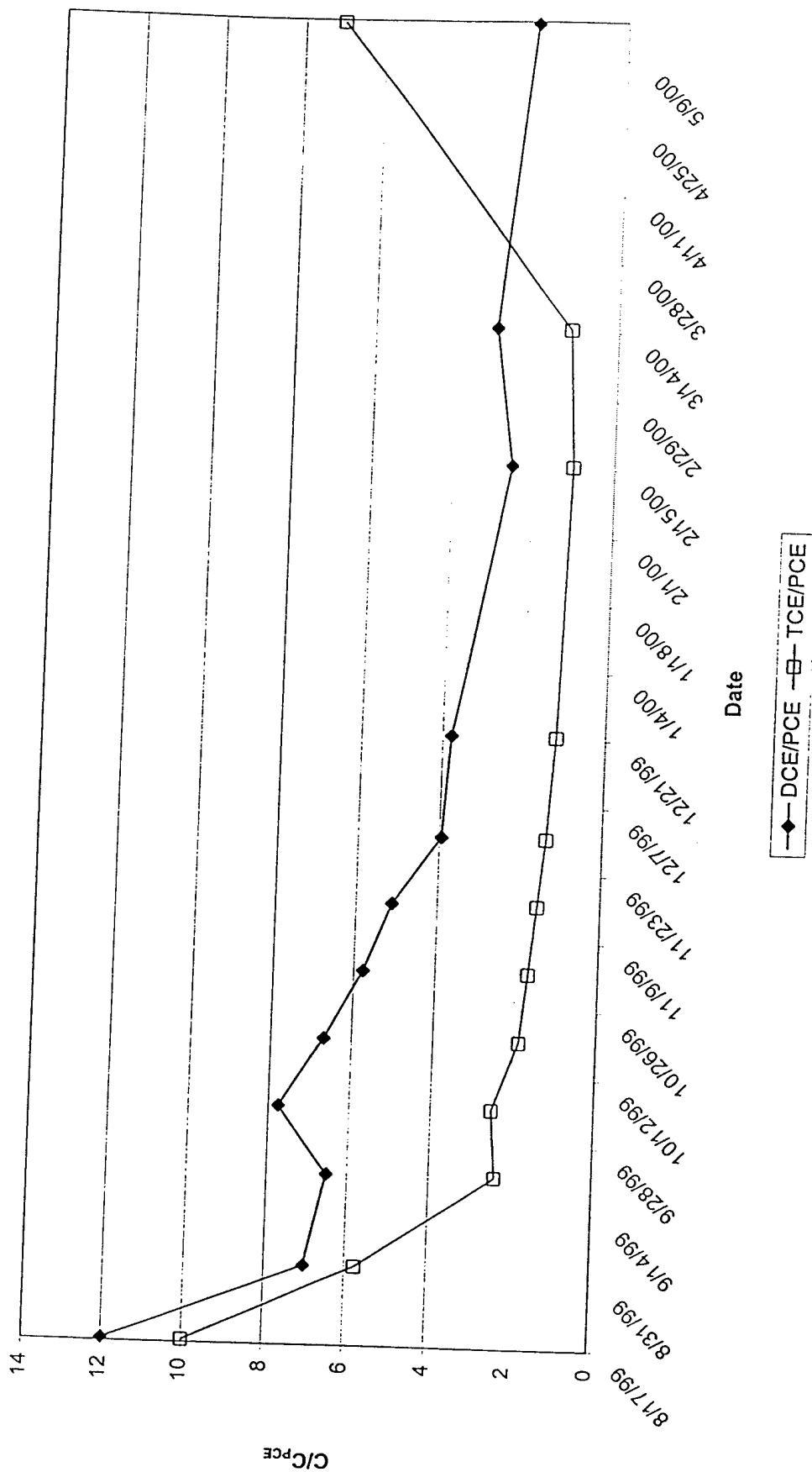


Figure 3.2.6.15  
 MW 3: Selected VOC Concentrations Relative to PCE vs. Time  
 Naval Air Engineering Station  
 Lakehurst, New Jersey

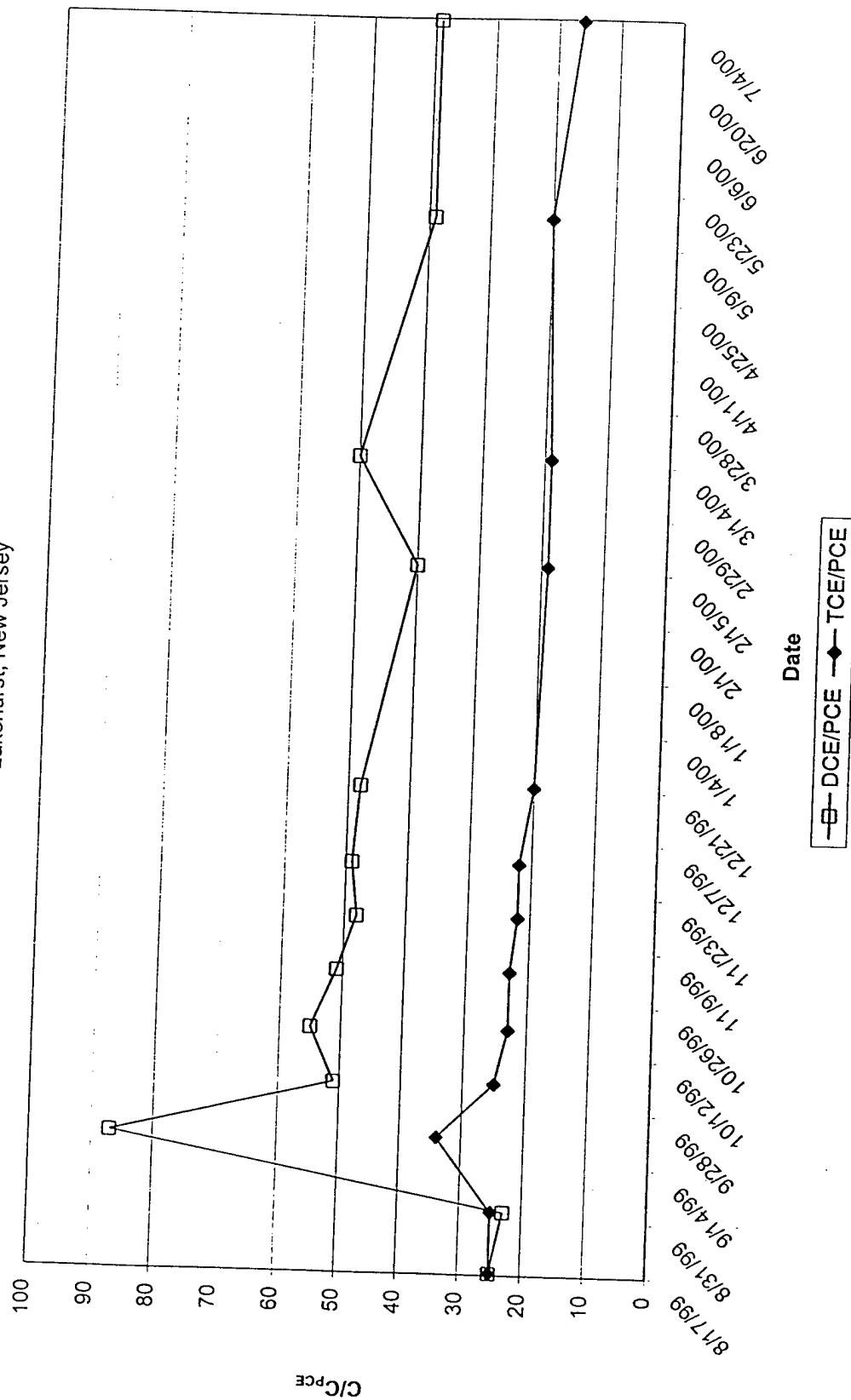


Figure 3.2.6.16  
MW4: Selected VOC Concentrations Relative to PCE vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

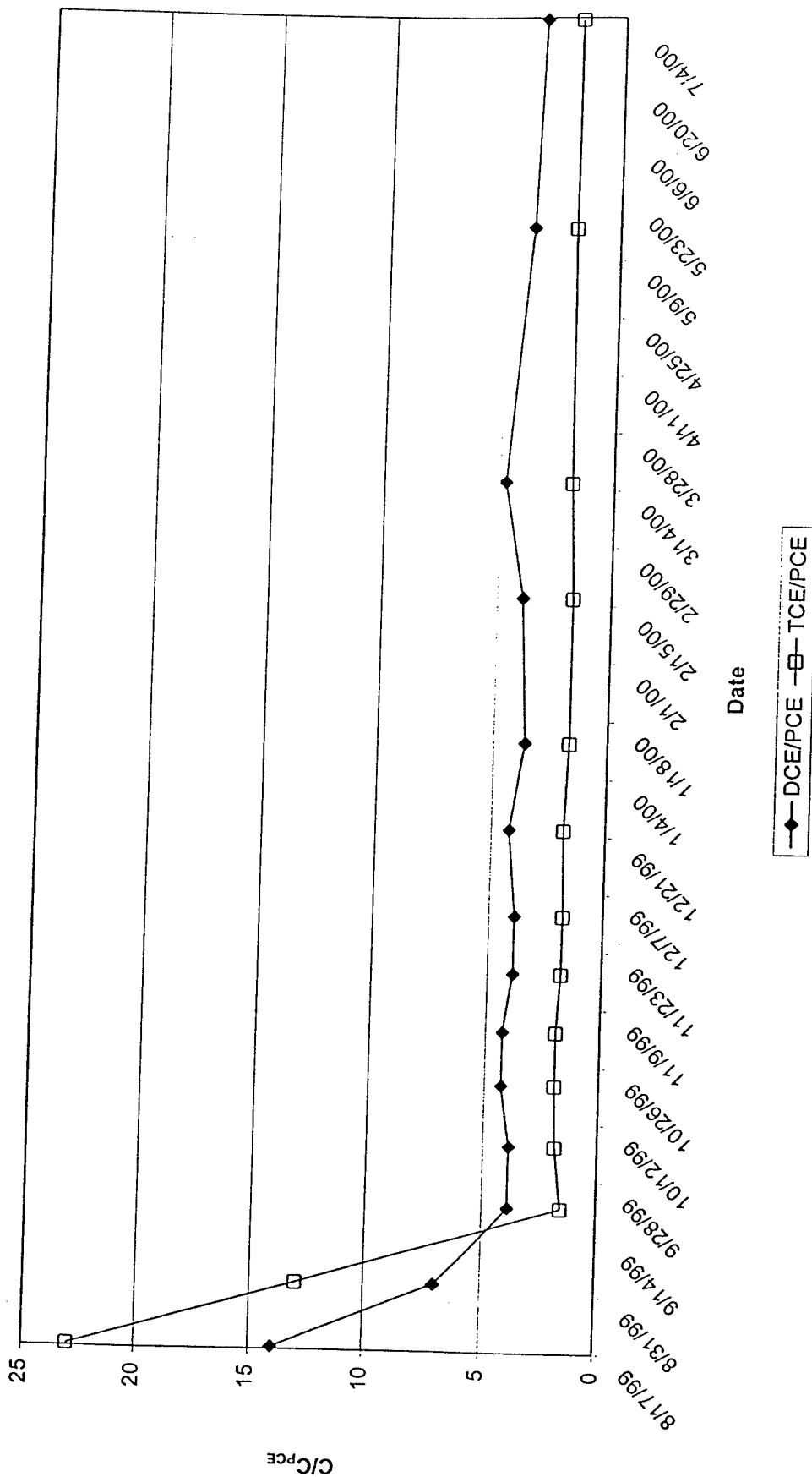


Figure 3.2.6.17  
MW5: Selected VOC Concentrations Relative to PCE vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

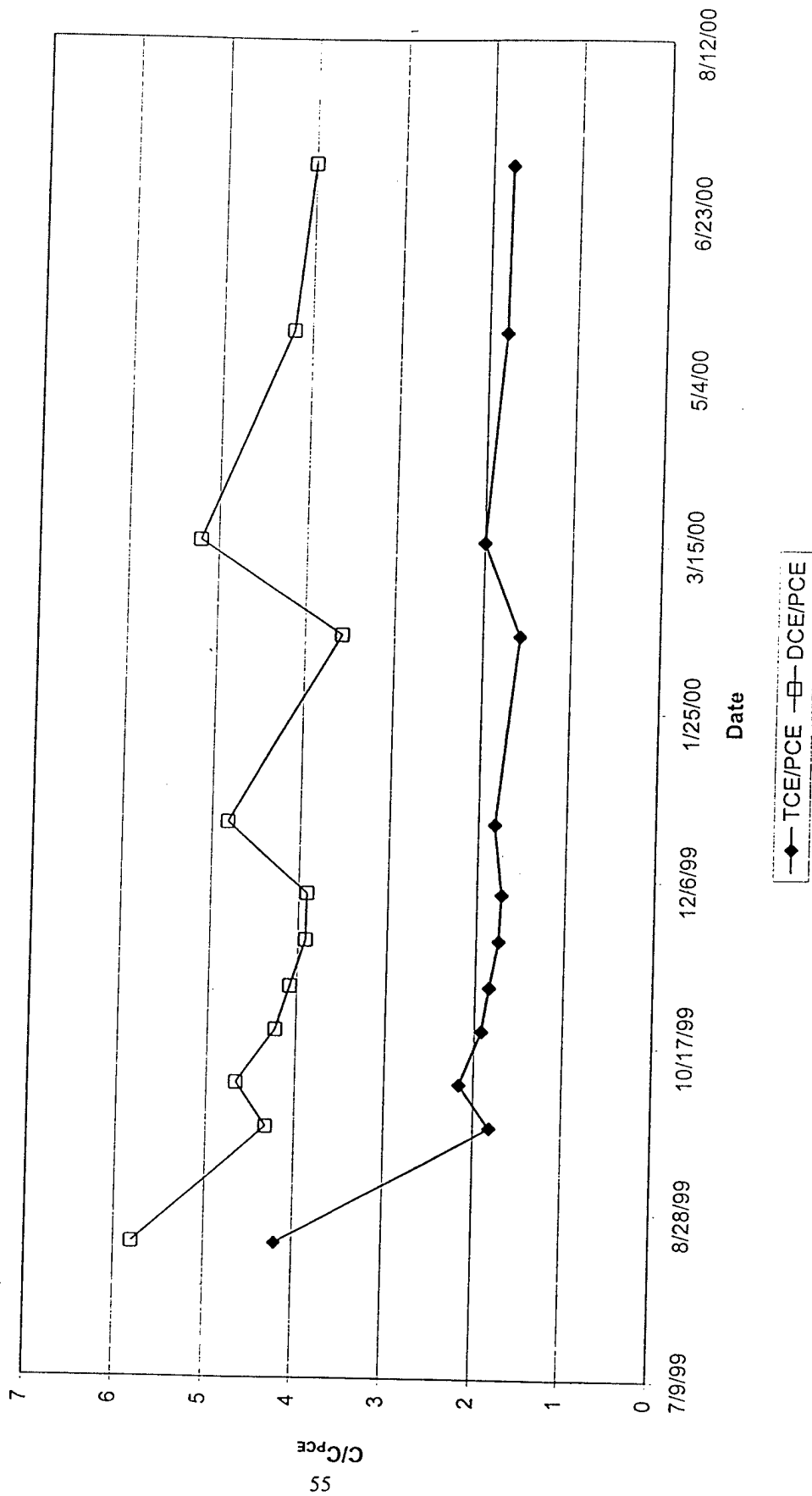




Figure 3.2.6.18  
MW8: Selected VOC Concentrations Relative to PCE vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

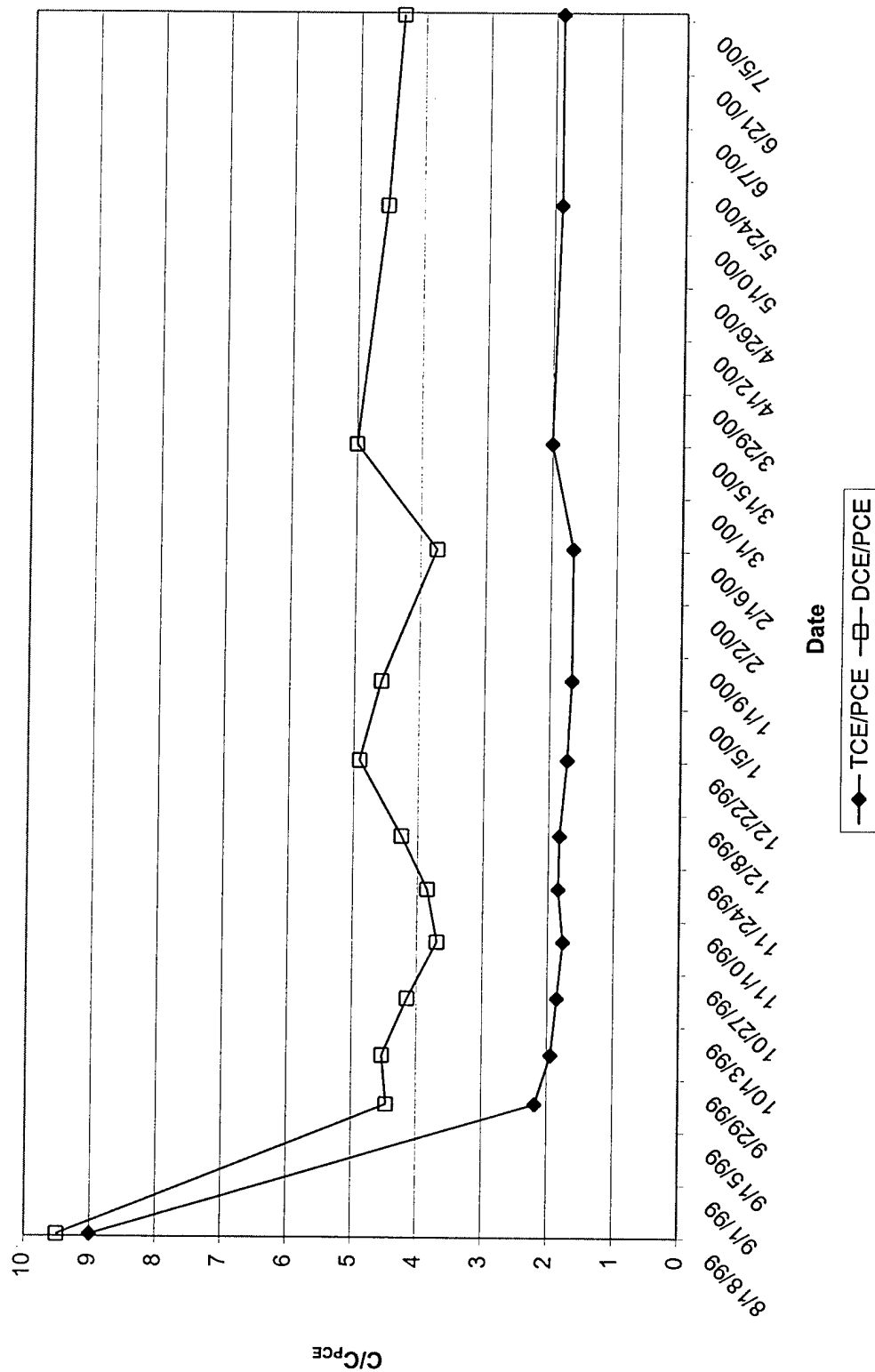


Figure 3.2.6.19  
Well LK: Selected VOC Concentrations Relative to PCE vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

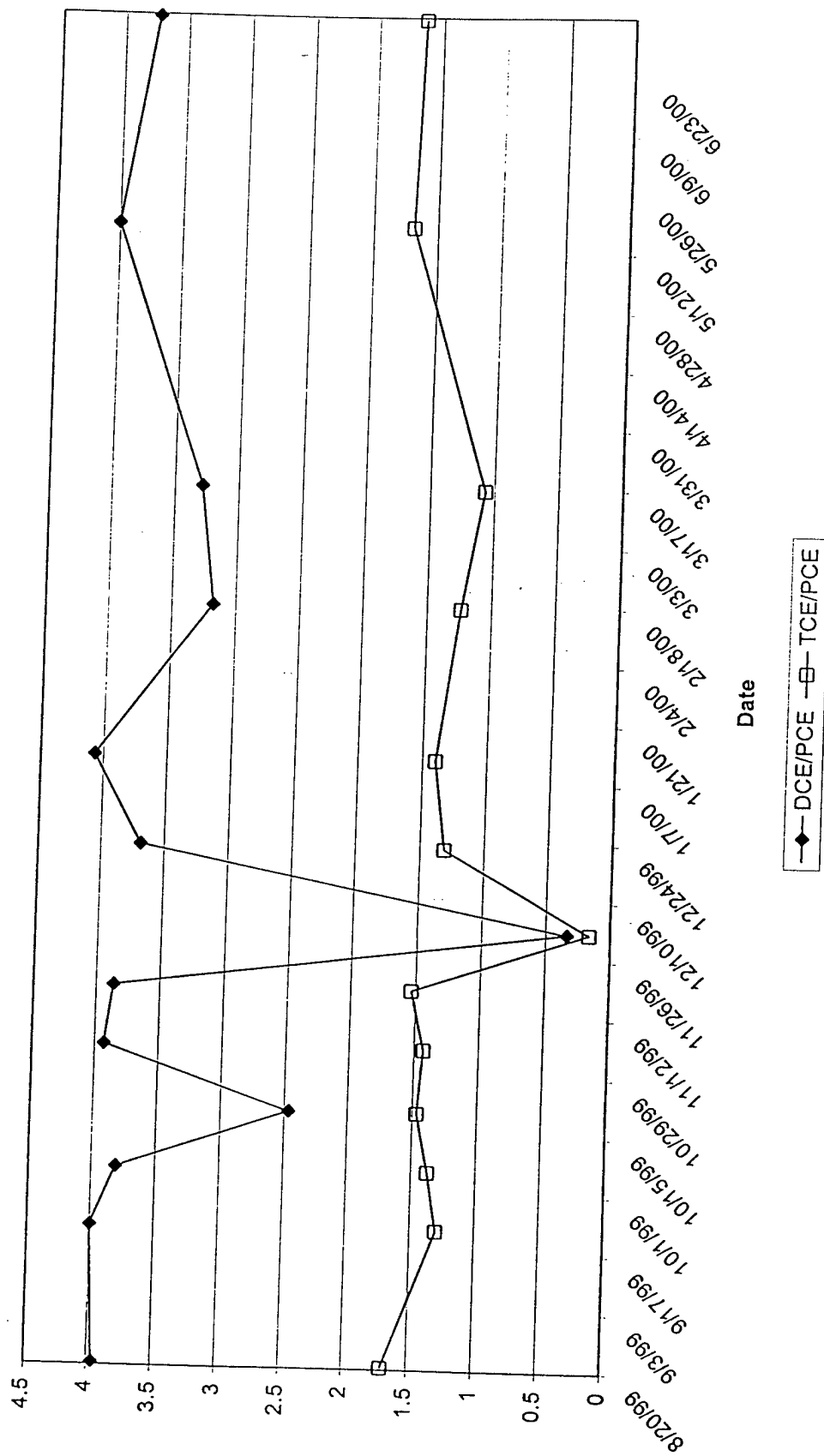


Figure 3.2.6.20  
RW1: Selected VOC Concentrations Relative to PCE vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey

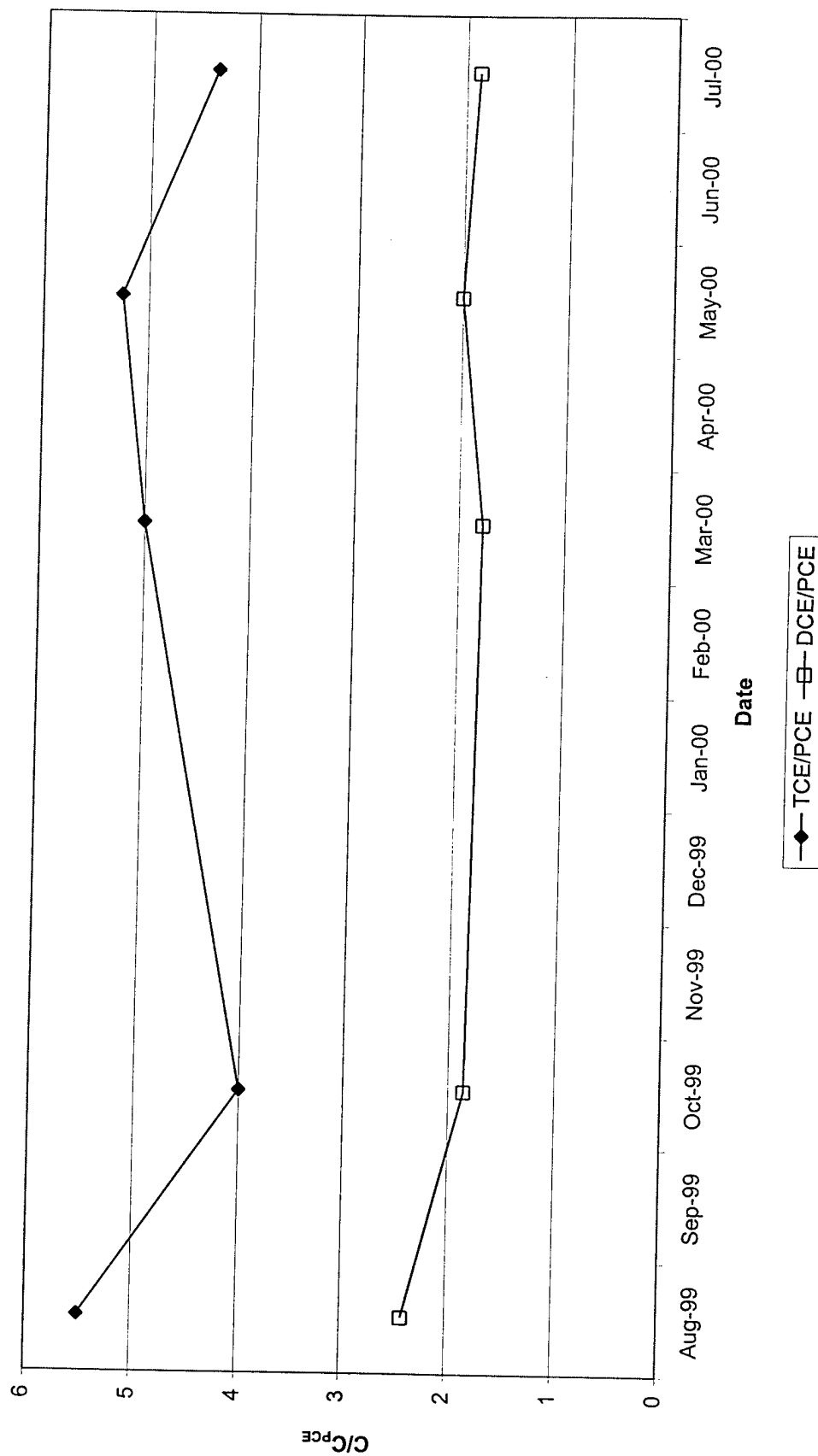
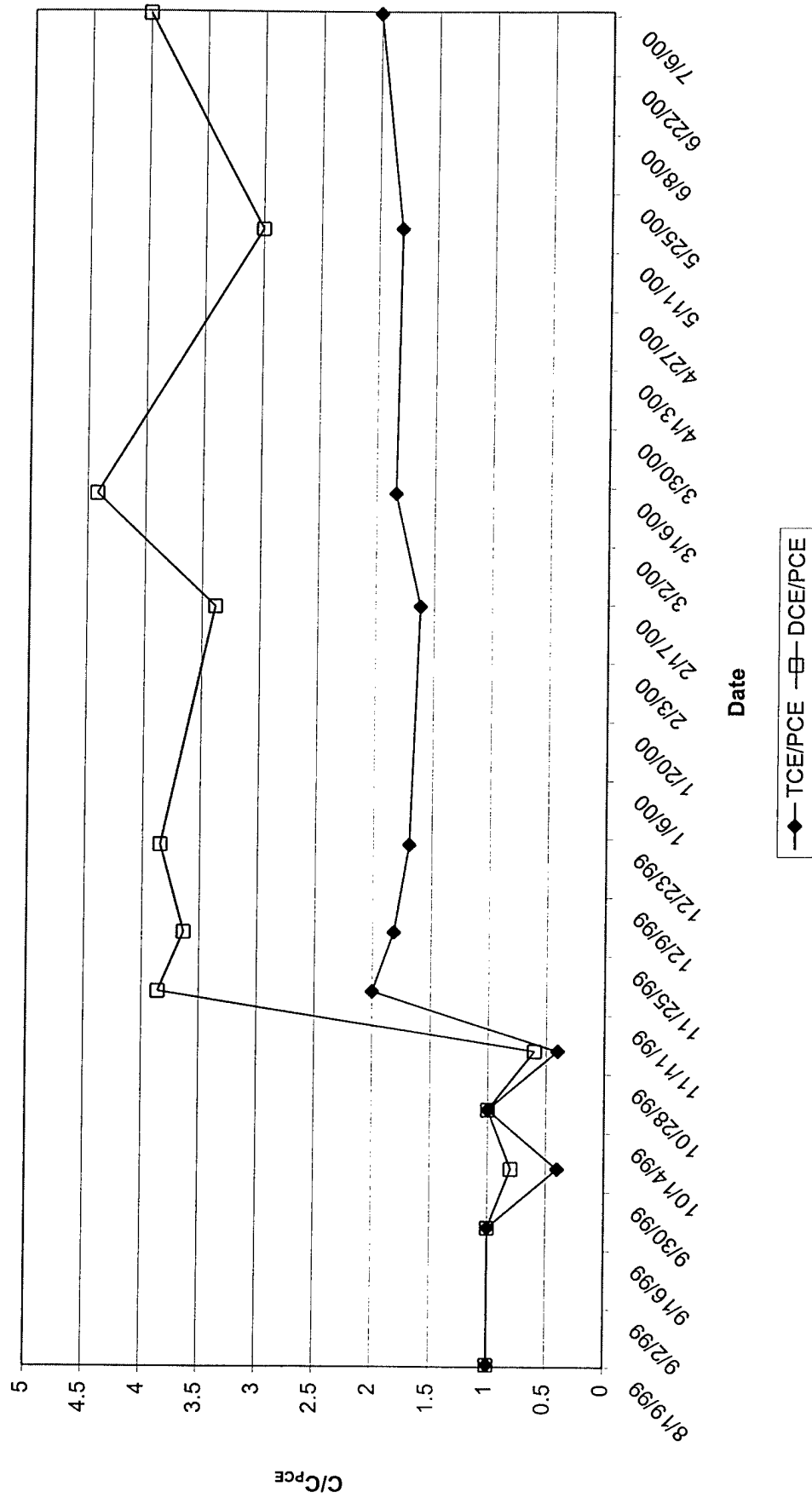


Figure 3.2.6.21  
OW 5: Selected VOC Concentrations Relative to PCE vs. Time

Naval Air Engineering Station  
Lakehurst, New Jersey



## **APPENDIX A**

### **Low Flow Sampling SOP**

**U.S. ENVIRONMENTAL PROTECTION AGENCY  
REGION I**

**LOW STRESS (low flow) PURGING AND SAMPLING  
PROCEDURE FOR THE COLLECTION OF  
GROUND WATER SAMPLES  
FROM MONITORING  
WELLS**



**July 30, 1996  
Revision 2**

U.S. ENVIRONMENTAL PROTECTION AGENCY  
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE  
FOR THE COLLECTION OF GROUND WATER SAMPLES  
FROM MONITORING WELLS

I. SCOPE & APPLICATION

This standard operating procedure (SOP) provides a general framework for collecting ground water samples that are indicative of mobile organic and inorganic loads at ambient flow conditions (both the dissolved fraction and the fraction associated with mobile particulates). The SOP emphasizes the need to minimize stress by low water-level drawdowns, and low pumping rates (usually less than 1 liter/min) in order to collect samples with minimal alterations to water chemistry. This SOP is aimed primarily at sampling monitoring wells that can accept a submersible pump and have a screen, or open interval length of 10 feet or less (this is the most common situation). However, this procedure is flexible and can be used in a variety of well construction and ground-water yield situations. Samples thus obtained are suitable for analyses of ground water contaminants (volatile and semi-volatile organic analytes, pesticides, PCBs, metals and other inorganics), or other naturally occurring analytes.

This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPLs and DNAPLs). For this the reader may wish to check: Cohen, R.M. and J.W. Mercer, 1993, DNAPL Site Evaluation; C.K. Smoley (CRC Press), Boca Raton, Florida and U.S. Environmental Protection Agency, 1992, RCRA Ground-Water Monitoring: Draft Technical Guidance; Washington, DC (EPA/530-R-93-001).

The screen, or open interval of the monitoring well should be optimally located (both laterally and vertically) to intercept existing contaminant plume(s) or along flowpaths of potential contaminant releases. It is presumed that the analytes of interest move (or potentially move) primarily through the more permeable zones within the screen, or open interval.

Use of trademark names does not imply endorsement by U.S.EPA but is intended only to assist in identification of a specific type of device.

Proper well construction and development cannot be overemphasized, since the use of installation techniques that are appropriate to the hydrogeologic setting often prevents "problem well" situations from occurring. It is also recommended that as part of development or redevelopment the well should be tested to determine the appropriate pumping rate to obtain stabilization of field indicator parameters with minimal drawdown in shortest amount of time. With this information field crews can then conduct purging and sampling in a more expeditious manner.

The mid-point of the saturated screen length (which should not exceed 10 feet) is used by convention as the location of the pump intake. However, significant chemical or permeability contrast(s) within the screen may require additional field work to determine the optimum vertical location(s) for the intake, and appropriate pumping rate(s) for purging and sampling more localized target zone(s). Primary flow zones (high(er) permeability and/or high(er) chemical concentrations) should be identified in wells with screen lengths longer than 10 feet, or in wells with open boreholes in bedrock. Targeting these zones for water sampling will help insure that the low stress procedure will not underestimate contaminant concentrations. The Sampling and Analysis Plan must provide clear instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the remaining criteria in this procedure are met. If after 4 hours of purging indicator field parameters have not stabilized, one of 3 optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization) c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may not meet the sampling objectives).

Changes to this SOP should be proposed and discussed when the site Sampling and Analysis Plan is submitted for approval. Subsequent requests for modifications of an approved plan must include adequate technical justification for proposed changes. All changes and modifications must be approved before implementation in field.

## II. EQUIPMENT

### A. Extraction device

Adjustable rate, submersible pumps are preferred (for example, centrifugal or bladder pump constructed of stainless steel or



Teflon).

Adjustable rate, peristaltic pumps (suction) may be used with caution. Note that EPA guidance states: "Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" (EPA/540/P-87/001, 1987, page 8.5-11).

The use of inertial pumps is discouraged. These devices frequently cause greater disturbance during purging and sampling and are less easily controlled than the pumps listed above. This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

#### B. Tubing

Teflon or Teflon lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for inorganics analyses. However, these materials should be used with caution when sampling for organics. If these materials are used, the equipment blank (which includes the tubing) data must show that these materials do not add contaminants to the sample.

Stainless steel tubing may be used when sampling for VOCs, SVOCs, pesticides, and PCBs. However, it should be used with caution when sampling for metals.

The use of 1/4 inch or 3/8 inch (inner diameter) tubing is preferred. This will help ensure the tubing remains liquid filled when operating at very low pumping rates.

Pharmaceutical grade (Pharmed) tubing should be used for the section around the rotor head of a peristaltic pump, to minimize gaseous diffusion.

C. Water level measuring device(s), capable of measuring to 0.01 foot accuracy (electronic "tape", pressure transducer). Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level "tape" at the start and end of each record.

D. Flow measurement supplies (e.g., graduated cylinder and stop watch).

E. Interface probe, if needed.

F. Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate the samples.

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G. Indicator field parameter monitoring instruments - pH, Eh, dissolved oxygen (DO), turbidity, specific conductance, and temperature. Use of a flow-through-cell is required when measuring all listed parameters, except turbidity. Standards to perform field calibration of instruments. Analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846. For Eh measurements, follow manufacturer's instructions.

H. Decontamination supplies (for example, non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.).

I. Logbook(s), and other forms (for example, well purging forms).

J. Sample Bottles.

K. Sample preservation supplies (as required by the analytical methods).

L. Sample tags or labels.

M. Well construction data, location map, field data from last sampling event.

N. Well keys.

O. Site specific Sample and Analysis Plan/Quality Assurance Project Plan.

P. PID or FID instrument (if appropriate) to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

### III. PRELIMINARY SITE ACTIVITIES

Check well for security damage or evidence of tampering, record pertinent observations.

Lay out sheet of clean polyethylene for monitoring and sampling equipment.

Remove well cap and immediately measure VOCs at the rim of the well with a PID or FID instrument and record the reading in the field logbook.

If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook.

A synoptic water level measurement round should be performed (in the shortest possible time) before any purging and sampling activities begin. It is recommended that water level depth (to 0.01 ft.) and

total well depth (to 0.1 ft.) be measured the day before, in order to allow for re-settlement of any particulates in the water column. If measurement of total well depth is not made the day before, it should not be measured until after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe are usually not needed unless analytical data or field head space information signal a worsening situation. Note: procedures for collection of LNAPL and DNAPL samples are not addressed in this SOP.

#### IV. PURGING AND SAMPLING PROCEDURE

Sampling wells in order of increasing chemical concentrations (known or anticipated) is preferred.

##### 1. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the midpoint of the zone to be sampled. The Sampling and Analysis Plan should specify the sampling depth, or provide criteria for selection of intake depth for each well (see Section I). If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well. Collection of turbid free water samples may be especially difficult if there is two feet or less of standing water in the well.

##### 2. Measure Water Level

Before starting pump, measure water level. If recording pressure transducer is used-initialize starting condition.

##### 3. Purge Well

###### 3a. Initial Low Stress Sampling Event

Start the pump at its lowest speed setting and slowly increase the speed until discharge occurs. Check water level. Adjust pump speed until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceeds 0.3 feet but remains stable, continue purging until indicator field parameters stabilize.

Monitor and record water level and pumping rate every three to five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (for example, 0.1 - 0.4 l/min) to ensure stabilization of indicator

parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. Do not allow the water level to fall to the intake level (if the static water level is above the well screen, avoid lowering the water level into the screen). The final purge volume must be greater than the stabilized drawdown volume plus the extraction tubing volume.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (bladder, peristaltic), and/or the use of dedicated equipment. If the recharge rate of the well is lower than extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well should be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (ideally the intake should not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

#### 3b. Subsequent Low Stress Sampling Events

After synoptic water level measurement round, check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). Perform purging operations as above.

#### 4. Monitor Indicator Field Parameters

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, Eh, DO) every three to five minutes (or less frequently, if appropriate). Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at three (3) to five (5) minute intervals, are within the following limits:

- turbidity (10% for values greater than 1 NTU),
- DO (10%),
- specific conductance (3%),
- temperature (3%),
- pH ( $\pm 0.1$  unit),
- ORP/Eh ( $\pm 10$  millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values

measured within the cell and may also cause an underestimation of turbidity values measured after the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities.

The flow-through-cell must be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must be submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe should come first (this parameter is most susceptible to error if air leaks into the system).

#### 5. Collect Water Samples

Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell (use a by-pass assembly or disconnect cell to obtain sample).

VOC samples should be collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

During purging and sampling, the tubing should remain filled with water so as to minimize possible changes in water chemistry upon contact with the atmosphere. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use one of the following procedures to collect samples: (1) add clamp, connector (Teflon or stainless steel) or valve to constrict sampling end of tubing; (2) insert small diameter Teflon tubing into water filled portion of pump tubing allowing the end to protrude beyond the end of the pump tubing, collect sample from small diameter tubing; (3) collect non-VOC samples first, then increase flow rate slightly until the water completely fills the tubing, collect sample and record new drawdown, flow rate and new indicator field parameter values.

Add preservative, as required by analytical methods, to samples immediately after they are collected if the sample containers are not pre-preserved. Check analytical methods (e.g. EPA SW-846, water supply, etc.) for additional information on preservation. Check pH for all samples requiring pH adjustment to assure proper pH value. For VOC samples, this will require that a test sample be collected during purging to determine the amount of preservative that needs to be added to the sample containers prior to sampling.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter is required, and the filter

size (0.45 um is commonly used) should be based on the sampling objective. Pre-rinse the filter with approximately 25 - 50 ml of ground water prior to sample collection. Preserve filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in ground water for human health risk calculations.

Label each sample as collected. Samples requiring cooling (volatile organics, cyanide, etc.) will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

#### 6. Post Sampling Activities

If recording pressure transducer is used, remeasure water level with tape.

After collection of the samples, the pump tubing may either be dedicated to the well for resampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth is optional after the initial low stress sampling event. However, it is recommended if the well has a "silting" problem or if confirmation of well identity is needed.

Secure the well.

### V. DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and following sampling of each subsequent well. Pumps will not be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires which are in contact with the well) will be decontaminated by one of the procedures listed below.

#### Procedure 1

The decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump or the pump can be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and isopropyl alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Flush with isopropyl alcohol (pesticide grade). If equipment blank data from the previous sampling event show that the level of contaminants is insignificant, then this step may be skipped.

Flush with distilled/deionized water. The final water rinse must not be recycled.

#### Procedure 2

Steam clean the outside of the submersible pump.

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

#### **VI. FIELD QUALITY CONTROL**

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the ground water samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples shall be collected for each batch of samples (a batch may not exceed 20 samples). Trip blanks are required for the VOC samples at a frequency of one set per VOC sample cooler.

Field duplicate.

Matrix spike.

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Matrix spike duplicate.

Equipment blank.

Trip blank (VOCs).

Temperature blank (one per sample cooler).

Equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank will only include the pump in subsequent sampling rounds.

Collect samples in order from wells with lowest contaminant concentration to highest concentration. Collect equipment blanks after sampling from contaminated wells and not after background wells.

Field duplicates are collected to determine precision of sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

If split samples are to be collected, collect split for each analyte group in consecutive order (VOC original, VOC split, etc.). Split sample should be as identical as possible to original sample.

All monitoring instrumentation shall be operated in accordance with EPA analytical methods and manufacturer's operating instructions. EPA analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846 with exception of Eh, for which the manufacturer's instructions are to be followed. Instruments shall be calibrated at the beginning of each day. If a measurement falls outside the calibration range, the instrument should be re-calibrated so that all measurements fall within the calibration range. At the end of each day, check calibration to verify that instruments remained in calibration. Temperature measuring equipment, thermometers and thermistors, need not be calibrated to the above frequency. They should be checked for accuracy prior to field use according to EPA Methods and the manufacturer's instructions.

## VII. FIELD LOGBOOK

A field log shall be kept to document all ground water field monitoring activities (see attached example matrix), and record all of the following:

Well identification.

Well depth, and measurement technique.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and



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detection method.

Pumping rate, drawdown, indicator parameters values, and clock time, at the appropriate time intervals; calculated or measured total volume pumped.

Well sampling sequence and time of each sample collection.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analysis.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling equipment used, including trade names, model number, diameters, material composition, etc.

#### **VIII. DATA REPORT**

Data reports are to include laboratory analytical results, QA/QC information, and whatever field logbook information is needed to allow for a full evaluation of data useability.

## Page of

Location (Site/Facility Name)

Location (Site/Facility Name) \_\_\_\_\_ Date \_\_\_\_\_  
Well Number \_\_\_\_\_

$$\frac{\text{Depth to (below MP)}}{\text{top}} / \frac{\text{of screen}}{\text{bottom}}$$

Field Personnel \_\_\_\_\_

### Sampling Organization

Pump Intake at (ft. below MP) \_\_\_\_\_  
Purging Device; (pump type) \_\_\_\_\_

[illegible]

1. Pump dial setting (for example: hertz, cycles/min, etc).
2.  $\mu$ Siemens per cm (same as  $\mu$ mhos/cm) at 25°C.
3. Oxidation reduction potential (stand in for Eh).

## **APPENDIX B**

### **Summary of Volatile Organic Compound Concentrations**

# Summary of Volatile Organic Compound Concentration in MW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3418-1	3453-1	3481-6	3505-1	3532-1	3561-1	3606-1	3625-1	3673-1	3773-04	3842-02	3987-4
Sampling Date	08/17/99	09/02/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/15/00	03/14/00	05/16/00
Dichlorodifluoromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Vinyl Chloride	2 J	2 J	3 J	4 J	5 U	5 U	4 J	3 J	4 J	2 J	1 J	2 J
Bromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
MTBE	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Methylethyl ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
trichlorofluoromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloroethene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
carbon disulfide	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
methylene chloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,2-dichloroethene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
chloroform	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
THF	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
bromochloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,1-trichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
carbon tetrachloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trichloroethene	20	23	19	20	28	22	26	30	35	34	26	35
1,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
dlbromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-chlorovinyl ether	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
MIBK	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	2 J	4 J	8	8	15	13	17	22	29	33	22	5 J
Cis Dichloroethene	24	28	52	62	100	75	87	87	110	83	66	11
bromodichloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
toluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
cis-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

All Results in ug/l

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentration in MW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3418-1	3453-1	3481-6	3505-1	3532-1	3561-1	3605-1	3625-1	3673-1	3773-04	3842-02	3987-4
Sampling Date	08/17/99	09/02/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/15/00	03/14/00	05/16/00
2-hexanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	5 U	5 U
1,1,2-trichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dibromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dibromoethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
chlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
ethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,1,2-tetrachloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
m/p xylene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
o Xylene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
styrene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
isopropyl benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
bromoforn	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,2,2-tetrachloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,3-trichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
n-propyl benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
bromobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3,5-trimethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-chlorotoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-chlorotoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
tert-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,4-trimethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
sec-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
p-isopropyltoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
n-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,4-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dibromo-3-chloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,4-trichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
hexachlorobutadiene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
naphthalene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,3-trichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for MW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-01	3481-6	3505-1	3532-1	3561-1	3606-1	3625-1	3673-1	3773-04	3842-02	3987-4
Date	8/17/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/15/00	03/14/00	05/16/00
Chloride(1)	6.8	11.0	NA	NA	12	NA	12	NA	11	11	8.3
Nitrite as N	u	u	NA	NA	0.4	NA	0.40	NA	u	u	u
Nitrate as N	0.2	0.3	NA	NA	NA	NA	NA	NA	0.4	0.4	0.2
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA	NA	u	u	u
Sulfate as SO4	16	8.3	NA	NA	6.8	NA	7.8	NA	7.8	8.9	8.2
Ammonia as NH3-N	u	u	NA	NA	u	NA	NA	NA	0.7	1	u
Alkalinity as CaCO3	11	11	NA	NA	9	NA	7	NA	6	5	7
Carbon Dioxide (2)	41	64	65	86	75	67	73	39	56	82	84
Methane (2)	0.20	0.14	0.24	0.23	0.19	0.05	0.24	0.02	0.09	0.03	0.02
Ethane (2)	u	u	u	u	u	u	NA	u	u	u	u
Propane (2)	u	u	u	u	u	u	NA	u	u	u	u
Total Organic Carbon	u	8	NA	NA	NA	NA	NA	NA	u	u	u
pH*	5.74	5.48	NA	NA	5.1	NA	5.32	NA	5.26	5.21	5.2
Phosphate, total as P	0.04J	u	NA	NA	NA	NA	NA	NA	u	0.05	0.06
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected below Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for MW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-01	3481-6	3561-1	3625-1	3773-04	3842-02	3987-4
Date	8/17/99	09/21/99	11/02/99	11/30/99	02/15/00	03/14/00	05/16/00
Total Heterotrophs	1,300	u	u	u	u	u	u
Specific Heterotrophs (1,2)*	490	u	u	u	u	u	u

## Explanation:

All Results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected below Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for MW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-1	3481-6	3505-1	3532-1	3561-1	3606-1	3625-1	3673-1	3773-4	3842-2	3842-3 (DUP)	3987-4
Date	8/17/99	9/21/99	10/5/99	10/19/99	10/2/99	11/16/99	11/30/99	12/21/99	2/15/00	3/14/00	3/14/00	5/16/00
Iron	7,240	2,650	7,907	1,898	2,410	1,630	1,940	1,420	5,150	4,680	5,860	5,400
Iron (Dissolved)	4,220	3,470	3,455	1,847	2,010	967	1,610	1,400	1,780	2,100	2,420	3,060

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J= Estimated value: compound detected below Practical Quantitation Limit



# Summary of Volatile Organic Compound Concentrations in MW-2

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3418-2	3481-3	3505-7	3532-4	3561-4	3606-4	3627-1	3673-4	3698-4	3778-02	3842-04	3987-7
Sampling Date	08/17/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	12/01/99	12/21/99	01/12/00	02/16/00	03/14/00	05/16/00
Dichlorodifluoromethane	5	U	U	U	U	U	U	U	U	U	U	U
Chloromethane	5	U	U	U	U	U	U	U	U	U	U	U
Vinyl Chloride	6	8	6	4	3	2	2	2	2	1	1	1
Bromomethane	5	U	U	U	U	U	U	U	U	U	U	U
Chloroethane	5	U	U	U	U	U	U	U	U	U	U	U
MTBE	5	U	U	U	U	U	U	U	U	U	U	U
Methylethyl ketone	10	U	U	U	U	U	U	U	U	U	U	U
Acetone	10	U	U	U	U	U	U	U	U	U	U	U
trichlorofluoromethane	5	U	U	U	U	U	U	U	U	U	U	U
1,1-dichloroethene	5	U	U	U	U	U	U	U	U	U	U	U
carbon disulfide	5	U	U	U	U	U	U	U	U	U	U	U
methylene chloride	5	U	U	U	U	U	U	U	U	U	U	U
trans-1,2-dichloroethene	5	U	U	U	U	U	U	U	U	U	U	U
1,1-dichloroethane	5	U	U	U	U	U	U	U	U	U	U	U
2,2-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U
chloroform	5	U	U	U	U	U	U	U	U	U	U	U
THF	10	U	U	U	U	U	U	U	U	U	U	U
bromochloromethane	5	U	U	U	U	U	U	U	U	U	U	U
1,1,1-trichloroethane	5	U	U	U	U	U	U	U	U	U	U	U
1,1-dichloropropene	5	U	U	U	U	U	U	U	U	U	U	U
carbon tetrachloride	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dichloroethane	5	U	U	U	U	U	U	U	U	U	U	U
Benzene	5	U	U	U	U	U	U	U	U	U	U	U
trichloroethene	23	33	55	64	61	49	25	21	22	20	21	23
1,2-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U
tribromomethane	5	U	U	U	U	U	U	U	U	U	U	U
2-chlorovinyl ether	10	U	U	U	U	U	U	U	U	U	U	U
MBK	10	U	U	U	U	U	U	U	U	U	U	U
Tetrachloroethene	9	22	46	69	64	44	15	11	10	10	10	10
Cis Dichloroethene	55	110	150	170	150	100	50	51	49	45	53	43
bromodichloromethane	5	U	U	U	U	U	U	U	U	U	U	U
trans-1,3-dichloropropene	5	U	U	U	U	U	U	U	U	U	U	U
toluene	5	U	U	U	U	U	U	U	U	U	U	U
cis-1,3-dichloropropene	5	U	U	U	U	U	U	U	U	U	U	U

All results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in MW-2

Naval Air Engineering Station  
Lakelhurst, New Jersey

Laboratory Sample Number	3418-2	3481-3	3505-7	3532-4	3561-4	3608-4	3627-1	3673-4	3698-4	3776-02	3842-04	3987-7
Sampling Date	08/17/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	12/01/99	12/21/99	01/12/00	02/16/00	03/14/00	05/16/00
2-hexanone	10	U	10	U	U	U	U	U	U	U	U	U
1,1,2-trichloroethane	5	U	5	U	5	U	5	U	5	U	5	U
1,3-dichloropropane	5	U	5	U	5	U	5	U	5	U	5	U
1,2-dibromoethane	5	U	5	U	5	U	5	U	5	U	5	U
1,2-dibromoethane	5	U	5	U	5	U	5	U	5	U	5	U
chlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U
ethylbenzene	5	U	5	U	5	U	5	U	5	U	5	U
1,1,1,2-tetrachloroethane	5	U	47	5	U	5	U	5	U	5	U	U
m/p xylene	5	U	5	U	5	U	5	U	5	U	5	U
o xylene	5	U	5	U	5	U	5	U	5	U	5	U
styrene	5	U	5	U	5	U	5	U	5	U	5	U
isopropyl benzene	5	U	5	U	5	U	5	U	5	U	5	U
bromoform	5	U	5	U	5	U	5	U	5	U	5	U
1,1,2,2-tetrachloroethane	5	U	5	U	5	U	5	U	5	U	5	U
1,2,3-trichloropropane	5	U	5	U	5	U	5	U	5	U	5	U
n-propyl benzene	5	U	5	U	5	U	5	U	5	U	5	U
bromobenzene	5	U	5	U	5	U	5	U	5	U	5	U
1,3,5-trimethylbenzene	5	U	5	U	5	U	5	U	5	U	5	U
2-chlorotoluene	5	U	5	U	5	U	5	U	5	U	5	U
4-chlorotoluene	5	U	5	U	5	U	5	U	5	U	5	U
tert-butylbenzene	5	U	5	U	5	U	5	U	5	U	5	U
1,2,4-trimethylbenzene	5	U	5	U	5	U	5	U	5	U	5	U
sec-butylbenzene	5	U	5	U	5	U	5	U	5	U	5	U
p-isopropyltoluene	5	U	5	U	5	U	5	U	5	U	5	U
1,3-dichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U
1,2-dichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U
n-butylbenzene	5	U	5	U	5	U	5	U	5	U	5	U
1,4-dichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U
1,2-dibromo-3-chloropropane	5	U	5	U	5	U	5	U	5	U	5	U
1,2,4-trichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U
hexachlorobutadiene	5	U	5	U	5	U	5	U	5	U	5	U
naphthalene	5	U	5	U	5	U	5	U	5	U	5	U
1,2,3-trichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U

All results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for MW-2

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-02	3481-3	3505-7	3532-4	3532-9 (DUP)	3561-4	3561-5 (DUP)
Date	8/17/99	09/21/99	10/05/99	10/19/99	10/19/99	11/02/99	11/02/99
Chloride(1)	14.0	15.0	NA	NA	NA	11	11
Nitrite as N	u	u	NA	NA	NA	0.4	0.4
Nitrate as N	0.2	0.7	NA	NA	NA	NA	NA
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA
Sulfate as SO4	13	6.4	NA	NA	NA	10	9.7
Ammonia as NH3-N	u	u	NA	NA	NA	u	u
Alkalinity as CaCO3	18	7	NA	NA	NA	4	6
Carbon Dioxide (2)	52	92	77	88	98	77	87
Methane (2)	0.26	0.33	0.26	0.109	0.153	0.042	0.038
Ethane (2)	u	u	u	u	u	u	u
Ethene (2)	u	u	u	u	u	u	u
Propane (2)	u	u	u	u	u	u	u
Total Organic Carbon	u	15	NA	NA	NA	NA	NA
pH*	5.71	5.38	NA	NA	NA	5.04	5.08
Phosphate, total as P	0.04J	u	NA	NA	NA	NA	NA
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for MW-2

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3606-4	3627-1	3673-4	3698-4	3698-8	3842-04	3987-7
Date	11/16/99	12/01/99	12/21/99	01/12/00	1/12/00	03/14/00	05/16/00
Chloride(1)	NA	11	NA	11	9.4	9.8	8.8
Nitrite as N	NA	0.2	NA	u	u	u	u
Nitrate as N	NA	NA	NA	0.2	0.2	0.3	0.2
Phosphate as P, ortho	NA	NA	NA	u	u	u	u
Sulfate as SO4	NA	18	NA	13	8.7	7.6	2.9
Ammonia as NH3-N	NA	NA	NA	0.6	1.6	0.7	u
Alkalinity as CaCO3	NA	4	NA	3	7	3	7
Carbon Dioxide (2)	84	60	61	93	82	u	75
Methane (2)	0.035	0.027	0.039	0.009	u	u	0.002
Ethane (2)	u	NA	u	u	u	u	0.004
Propane (2)	u	NA	u	u	u	u	u
Total Organic Carbon	NA	NA	NA	u	u	0.76	1.04
pH*	NA	5.25	NA	u	u	u	u
Phosphate, total as P	NA	NA	NA	5.01	5.25	4.95	5.14
Sulfide (1, applied)	NA	NA	NA	u	u	u	u
				NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for MW-2

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-02	3481-3	3561-4	3561-5	3627-1	3698-4	3698-8	3842-04	3987-7
Date	8/17/99	09/21/99	11/02/99	11/02/99	12/01/99	01/12/00	1/12/00	03/14/00	05/16/00
Total Heterotrophs	1,100	u	u	u	u	200J	240J	u	u
Specific Heterotrophs (1,2)*	u	u	u	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for MW-2

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-2	3481-3	3505-7	3532-4	3532-9 (DUP)	3561-4	3561-5 (DUP)
Date	8/17/99	9/21/99	10/5/99	10/19/99	10/19/99	11/2/99	11/2/99
Iron	2,120	253	346	112	271	83	82
Iron (Dissolved)	1,540	818	136	107	117	79	72

Lab ID	3606-4	3627-1	3673-4	3698-4	3698-8 (DUP)	3842-4	3987-7
Date	11/16/99	12/1/99	12/21/99	1/12/00	1/12/00	3/14/00	5/16/00
Iron	u	u	u	97.6B	157	157B	238
Iron (Dissolved)	u	u	u	410	71.9B	110B	200

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J= Estimated value: compound detected below Practical Quantitation Limit

# Summary of Volatile Organic Compound Concentrations in MW-3

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3418-3	3453-2	3481-1	3505-9	3532-5	3563-4	3608-1	3627-2	3673-5	3776-03	3846-04	3987-8	4131-09
Sampling Date	08/17/99	09/02/99	09/21/99	10/05/99	10/19/99	11/03/99	11/17/99	12/01/99	12/21/99	02/16/00	03/15/00	05/16/00	07/06/00
Dichlorodifluoromethane	5	U	5	U	U	U	U	U	U	U	U	U	U
Chloromethane	5	U	5	U	U	U	U	U	U	U	U	U	U
Vinyl Chloride	1	U	6	4	U	U	U	U	U	U	U	U	U
Bromomethane	5	U	5	U	U	U	U	U	U	U	U	U	U
Chloroethane	5	U	5	U	U	U	U	U	U	U	U	U	U
MTBE	5	U	5	U	U	U	U	U	U	U	U	U	U
Methyl ethyl ketone	10	U	10	U	U	U	U	U	U	U	U	U	U
Acetone	10	U	10	U	U	U	U	U	U	U	U	U	U
trichlorofluoromethane	5	U	5	U	U	U	U	U	U	U	U	U	U
1,1-dichloroethane	5	U	5	U	U	U	U	U	U	U	U	U	U
carbon disulfide	5	U	5	U	U	U	U	U	U	U	U	U	U
methylene chloride	5	U	5	U	U	U	U	U	U	U	U	U	U
trans-1,2-dichloroethane	5	U	5	U	U	U	U	U	U	U	U	U	U
1,1-dichloroethane	5	U	5	U	U	U	U	U	U	U	U	U	U
2,2-dichloropropane	5	U	5	U	U	U	U	U	U	U	U	U	U
chloroform	5	U	5	U	U	U	U	U	U	U	U	U	U
THF	10	U	10	U	U	U	U	U	U	U	U	U	U
bromochloromethane	5	U	5	U	U	U	U	U	U	U	U	U	U
1,1,1-trichloroethane	5	U	5	U	U	U	U	U	U	U	U	U	U
1,1-dichloropropene	5	U	5	U	U	U	U	U	U	U	U	U	U
carbon tetrachloride	5	U	5	U	U	U	U	U	U	U	U	U	U
1,2-dichloroethane	5	U	5	U	U	U	U	U	U	U	U	U	U
Benzene	5	U	5	U	U	U	U	U	U	U	U	U	U
trichloroethene	25	U	34	25	23	23	22	22	20	19	19	20	16
1,2-dichloropropane	5	U	5	U	U	U	U	U	U	U	U	U	U
dibromomethane	5	U	5	U	U	U	U	U	U	U	U	U	U
2-chlorovinyl ether	10	U	10	U	U	U	U	U	U	U	U	U	U
MIBK	10	U	10	U	U	U	U	U	U	U	U	U	U
Tetrachloroethene	4	5	20	11	13	13	13	13	12	11	10	11	9
Cis Dichloroethene	25	23	87	51	55	51	48	49	48	40	50	39	39
bromodichloromethane	5	U	5	U	U	U	U	U	U	U	U	U	U
trans-1,3-dichloropropene	5	U	5	U	U	U	U	U	U	U	U	U	U
toluene	5	U	5	U	U	U	U	U	U	U	U	U	U
cis-1,3-dichloropropene	5	U	5	U	U	U	U	U	U	U	U	U	U

All Results in ug/l

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in MW-3

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3418-3	3453-2	3481-1	3505-9	3532-5	3563-4	3608-1	3627-2	3673-5	3776-03	3846-04	3987-8	4131-09
Sampling Date	08/17/99	09/02/99	09/21/99	10/05/99	10/19/99	11/03/99	11/17/99	12/07/99	12/21/99	02/16/00	03/15/00	05/16/00	07/06/00
2-hexanone	10	U	U	U	U	U	U	U	U	U	U	U	U
1,1,2-trichloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,3-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromomethane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	U	U	U	U	U
chlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
ethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,1,1,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U
m/p xylene	5	U	U	U	U	U	U	U	U	U	U	U	U
o Xylene	5	U	U	U	U	U	U	U	U	U	U	U	U
styrene	5	U	U	U	U	U	U	U	U	U	U	U	U
isopropyl benzene	5	U	U	U	U	U	U	U	U	U	U	U	U
bromofom	5	U	U	U	U	U	U	U	U	U	U	U	U
1,1,2,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U
n-propyl benzene	5	U	U	U	U	U	U	U	U	U	U	U	U
bromobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,3,5-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
2-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U	U
4-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U	U
tert-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
sec-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
p-isopropyltoluene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,3-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
n-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,4-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromo-3-chloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U
hexachlorobutadiene	5	U	U	U	U	U	U	U	U	U	U	U	U
naphthalene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit



# Summary of Limited Chemistry Analysis for MW-3

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-03	3481-1	3505-9	3532-5	3563-4	3608-1	3627-2
Date	8/17/99	09/21/99	10/05/99	10/19/99	11/03/99	11/17/99	12/01/99
Chloride(1)	7.0	11.0	NA	NA	9.5	NA	10
Nitrite as N	u	u	NA	NA	0.2	NA	0.2
Nitrate as N	0.2	0.2	NA	NA	NA	NA	NA
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA
Sulfate as SO4	11	9	NA	NA	6.5	NA	7.9
Ammonia as NH3-N	u	0.8	NA	NA	u	NA	NA
Alkalinity as CaCO3	14	9	NA	NA	8	NA	6
Carbon Dioxide (2)	43	97	84	82	84	72	64
Methane (2)	0.22	0.31	0.14	0.085	0.018	u	u
Ethane (2)	u	u	u	u	u	u	NA
Ethene (2)	u	u	u	u	u	u	NA
Propane (2)	u	u	u	u	u	u	NA
Total Organic Carbon	u	78	NA	NA	NA	NA	NA
pH*	5.96	5.39	NA	NA	5.31	NA	5.44
Phosphate, total as P	u	u	NA	NA	NA	NA	NA
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for MW-3

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3673-5	3750-03	3776-03	3846-04	3987-8	4131-9
Date	12/21/99	02/02/00	02/16/00	03/15/00	05/16/00	07/06/00
Chloride(1)	NA	NA	8.9	9.1	9.3	10
Nitrite as N	NA	NA	u	u	u	u
Nitrate as N	NA	NA	0.3	0.2	0.2	0.25
Phosphate as P, ortho	NA	NA	u	u	u	u
Sulfate as SO4	NA	NA	8.6	10	9.2	9
Ammonia as NH3-N	NA	NA	u	0.5	u	0.54
Alkalinity as CaCO3	NA	NA	4	3	4	3
Carbon Dioxide (2)	44	NA	78	94	57	87
Methane (2)	0.016	NA	u	u	0.003	u
Ethane (2)	u	NA	u	u	u	u
Ethene (2)	u	NA	u	u	u	u
Propane (2)	u	1.25	1.7	0.74	0.676	3.05
Total Organic Carbon	NA	NA	u	u	u	u
pH*	NA	NA	5.03	4.95	4.85	4.95
Phosphate, total as P	NA	NA	u	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for MW-3

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-03	3481-1	3563-4	3627-2	3776-03	3846-04	3987-8	4131-9
Date	8/17/99	09/21/99	11/03/99	12/01/99	02/16/00	03/15/00	05/16/00	07/06/00
Total Heterotrophs	360	u	u	370	320	u	u	u
Specific Heterotrophs (1,2)*	300	u	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for MW-3

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-3	3481-1	3505-9	3532-5	3563-4	3608-1	3627-2	3673-5	3776-3	3846-4	3987-8	4131-9
Date	8/17/99	9/21/99	10/5/99	10/19/99	11/3/99	11/17/99	12/1/99	12/21/99	2/16/00	3/15/00	5/16/00	7/6/00
Iron	7,830	2,870	2,080	1,065	692	742	476	207	99.3B	170B	5	442
Iron (Dissolved)	5,790	2,660	1,556	701	211	207	383	215	u	u	u	117

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J= Estimated value: compound detected below Practical Quantitation Limit

# Summary of Volatile Organic Compound Concentrations in MW-4

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3418-4	3453-3	3481-2	3508-1	3542-2	3563-7	3608-2	3627-3	3677-1	3698-5	3776-04	3846-03	3987-9	4131-04
Sampling Date	08/17/99	09/02/99	09/21/99	10/06/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	01/12/00	02/16/00	03/15/00	05/16/00	07/06/00
Dichlorodifluoromethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
Chloromethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
Vinyl Chloride	0	U	6	7	4	3	2	1	1	1	1	U	U	U
Bromomethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
Chloroethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
MTBE	5	U	5	U	U	5	U	U	5	U	5	U	U	U
Methylethyl ketone	10	U	10	U	U	10	U	U	10	U	10	U	U	U
Acetone	10	U	10	U	U	10	U	U	10	U	10	U	U	U
trichlorofluoromethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
1,1-dichloroethene	5	U	5	U	U	5	U	U	5	U	5	U	U	U
carbon disulfide	5	U	5	U	U	5	U	U	5	U	5	U	U	U
methylene chloride	5	U	5	U	U	5	U	U	5	U	5	U	U	U
trans-1,2-dichloroethene	5	U	5	U	U	5	U	U	5	U	5	U	U	U
1,1-dichloroethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
2,2-dichloropropane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
chloroform	5	U	5	U	U	5	U	U	5	U	5	U	U	U
THF	10	U	10	U	U	10	U	U	10	U	10	U	U	U
bromochloromethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
1,1,1-trichloroethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
1,1-dichloropropene	5	U	5	U	U	5	U	U	5	U	5	U	U	U
carbon tetrachloride	5	U	5	U	U	5	U	U	5	U	5	U	U	U
1,2-dichloroethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
Benzene	5	U	5	U	U	5	U	U	5	U	5	U	U	U
trichloroethene	23	28	31	35	23	23	23	21	20	20	20	20	21	17
1,2-dichloropropane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
tribromomethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
2-chlorovinyl ether	10	U	10	U	U	10	U	U	10	U	10	U	U	U
MIBK	10	U	10	U	U	10	U	U	10	U	10	U	U	U
Tetrachloroethene	1	J	2	19	12	12	13	12	11	12	12	11	11	9
Cis Dichloroethene	14	14	77	73	51	51	50	46	46	43	46	52	41	31
bromodichloromethane	5	U	5	U	U	5	U	U	5	U	5	U	U	U
trans-1,3-dichloropropene	5	U	5	U	U	5	U	U	5	U	5	U	U	U
toluene	5	U	5	U	U	5	U	U	5	U	5	U	U	U
cis-1,3-dichloropropene	5	U	5	U	U	5	U	U	5	U	5	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in MW-4

Naval Air Engineering Station  
Lakewood, New Jersey

Laboratory Sample Number	3418-4	3453-3	3481-2	3508-1	3542-2	3563-7	3608-2	3627-3	3677-1	3698-5	3776-04	3846-03	3987-9	4131-04
Sampling Date	08/17/99	09/02/99	09/21/99	10/06/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	01/12/00	02/16/00	03/15/00	05/16/00	07/05/00
2-hexanone	10	U	U	U	U	U	U	U	U	U	U	U	U	U
1,1,2-trichloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,3-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,1,1,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,1,1,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
m/p xylene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
o Xylene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
styrene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
isopropyl benzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
bromoforn	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,1,2,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
n-propyl benzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
bromobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,3,5-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
2-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
4-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
tert-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
sec-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
p-isopropyltoluene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,3-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
n-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,4-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromo-3-chloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
hexachlorobutadiene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
naphthalene	5	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for MW-4

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-04	3481-2	3508-1	3508-4	3542-2	3561-1	3608-2	3608-5	3627-3
Date	8/17/99	09/21/99	10/05/99	10/05/99	10/19/99	11/03/99	11/17/99	11/17/99	12/01/99
Chloride(1)	7.2	11.0	NA	NA	NA	9.6	NA	NA	10
Nitrite as N	u	u	NA	NA	NA	NA	NA	NA	NA
Nitrate as N	0.2	0.2	NA	NA	NA	0.2	NA	NA	0.2
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA	NA	NA
Sulfate as SO4	14	11	NA	NA	NA	5.8	NA	NA	7.2
Ammonia as NH3-N	u	u	NA	NA	NA	u	NA	NA	NA
Alkalinity as CaCO3	14	9	NA	NA	NA	7	NA	NA	6
Carbon Dioxide (2)	47	92	100	81	89	82	70	90	70
Methane (2)	0.15	0.31	0.26	0.12	0.12	0.03	u	u	u
Ethane (2)	u	u	u	u	u	u	u	u	NA
Ethene (2)	u	u	u	u	u	u	u	u	NA
Propane (2)	u	u	u	u	u	u	u	u	NA
Total Organic Carbon	u	15	NA	NA	NA	NA	NA	NA	NA
pH*	5.91	5.38	NA	NA	NA	5.24	NA	NA	5.33
Phosphate, total as P	u	u	NA	NA	NA	NA	NA	NA	NA
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for MW-4

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3677-1	3698-5	3698-8	3750-04	3776-04	3846-03	3987-9	4131-4
Date	12/22/99	01/12/00	01/12/00	02/02/00	02/16/00	03/15/00	05/16/00	7/6/00
Chloride(1)	NA	9.5	9.4	NA	9	8.9	9.3	10
Nitrite as N	NA	u	u	NA	u	u	u	u
Nitrate as N	NA	0.3	0.2	NA	0.2	0.2	0.2	0.24
Phosphate as P, ortho	NA	u	u	NA	u	u	u	u
Sulfate as SO4	NA	8.9	8.7	NA	6.6	9.2	9	9.2
Ammonia as NH3-N	NA	0.8	1.6	NA	u	u	u	0.56
Alkalinity as CaCO3	NA	6	7	NA	5	4	4	4
Carbon Dioxide (2)	75	77	82	NA	72	96	36	64
Methane (2)	0.02	u	u	NA	u	u	0.003	u
Ethane (2)	u	u	u	NA	u	u	0.007	u
Ethene (2)	u	u	u	NA	u	u	u	u
Propane (2)	u	u	u	u	2.96	0.72	1.48	1.58
Total Organic Carbon	NA	u	u	NA	u	u	u	u
pH*	NA	5.26	5.25	NA	5.07	4.87	4.81	5.29
Phosphate, total as P	NA	u	u	NA	u	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter



# Summary of Heterotroph Analysis in MW-4

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-4	3481-2	3563-7	3627-3	3698-5	3698-8 (DUP)	3776-4	3846-3	3987-9	4131-4
Date	8/17/99	9/21/99	11/3/99	12/01/99	01/12/00	01/12/00	02/16/00	03/15/00	05/16/00	7/6/00
Total Heterotrophs	1,900	u	u	540	u	240J	u	u	u	u
Specific Heterotrophs (1,2)*	530	u	u	u	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for MW-4

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3418-4	3481-2	3508-1	3508-4 (DUP)	3542-2	3563-7	3608-2	3608-5 (DUP)
Date	8/17/99	9/21/99	10/6/99	10/6/99	10/21/99	11/3/99	11/17/99	11/17/99
Iron	4,280	1,940	1,045	1,132	1,201	305	428	403
Iron (Dissolved)	3,710	2,080	878	877	663	u	283	162

Lab ID	3627-3	3677-1	3698-5	3776-4	3846-3	3987-9	4131-4
Date	12/1/99	12/22/99	1/12/00	2/16/00	3/15/00	5/16/00	7/6/00
Iron	90	63	75.5B	550	137B	40	187
Iron (Dissolved)	63	65	70.2B	u	52B	u	137

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J= Estimated value: compound detected below Practical Quantitation Limit

# Summary of Volatile Organic Compound Concentrations in MW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3422-1	3485-4	3505-4	3542-3	3563-5	3608-4	3627-5	3677-3	3776-06	3846-02	3995-6	4131-5
Sampling Date	08/18/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00	07/06/00
Dichlorodifluoromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Vinyl Chloride	7	14	5 J	4 J	3 J	1 J	1 J	1 J	1 J	5 U	1 J	1 J
Bromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
MTBE	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Methylethyl ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
trichlorofluoromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloroethene	2 J	2 U	5 U	5 U	5 U	0.5 J	5 J	5 J	5 J	5 J	5 J	5 J
carbon disulfide	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
methylene chloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,2-dichloroethene	5 U	5 U	5 U	5 U	5 U	0.7 J	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloroethane	5 U	5 U	5 U	5 U	5 U	0.6 J	5 U	5 U	0.6 J	5 U	5 U	5 U
2,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
chloroform	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
THF	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
bromochloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,1-trichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
carbon tetrachloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trichloroethene	42	40	26	25	24	21	19	20	19	20	18	16
1,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
dibromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-chlorovinyl ether	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
MIBK	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	10	22	12	13	13	12	11	11	12	10	10	9
Cis Dichloroethene	58	95	56	55	53	47	43	53	43	52	42	36
bromodichloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
toluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
cis-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in MW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3422-1	3485-4	3505-4	3542-3	3563-5	3608-4	3627-5	3677-3	3776-06	3846-02	3995-6	4131-5
Sampling Date	08/18/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00	07/06/00
2-hexanone	10	U	U	U	U	U	U	U	U	U	U	U
1,1,2-trichloroethane	5	U	U	U	U	U	U	U	U	U	U	U
1,3-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	U	U	U	U
chlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
ethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,1,1,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U
m/p xylene	5	U	U	U	U	U	U	U	U	U	U	U
o Xylene	5	U	U	U	U	U	U	U	U	U	U	U
styrene	5	U	U	U	U	U	U	U	U	U	U	U
isopropyl benzene	5	U	U	U	U	U	U	U	U	U	U	U
bromoforn	5	U	U	U	U	U	U	U	U	U	U	U
1,1,2,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichloropropane	5	U	U	U	U	U	U	U	U	U	U	U
n-propyl benzene	5	U	U	U	U	U	U	U	U	U	U	U
bromobenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,3,5-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
2-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U
4-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U
tert-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
sec-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
p-isopropyltoluene	5	U	U	U	U	U	U	U	U	U	U	U
1,3-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
n-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,4-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromo-3-chloropropane	5	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
hexachlorobutadiene	5	U	U	U	U	U	U	U	U	U	U	U
naphthalene	5	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for MW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-1	3481-6	3505-1	3542-3	3563-5	3608-4
Date	8/18/99	09/21/99	10/05/99	10/21/99	11/03/99	11/17/99
Chloride(1)	7.5	10.0	NA	NA	9.6	NA
Nitrite as N	u	u	NA	NA	NA	NA
Nitrate as N	0.1J	0.2	NA	NA	0.2	NA
Phosphate as P, ortho	u	0.2	NA	NA	NA	NA
Sulfate as SO4	15	7.8	NA	NA	5.5	NA
Ammonia as NH3-N	u	u	NA	NA	u	NA
Alkalinity as CaCO3	17	12	NA	NA	8	NA
Carbon Dioxide (2)	16	98	81	85	88	80
Methane (2)	0.35	0.33	0.12	0.03	0.01	u
Ethane (2)	u	u	u	u	u	u
Ethene (2)	u	u	u	u	u	u
Propane (2)	u	u	u	u	u	u
Total Organic Carbon	6	33	NA	NA	NA	NA
pH*	5.7		NA	NA	5.25	NA
Phosphate, total as P	u	5.42	NA	NA	NA	NA
Sulfide (1, applied)	NA	0.06	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for MW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3627-5	3677-3	3776-6	3846-2	3995-6	4131-5
Date	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00	7/6/00
Chloride(1)	10	NA	8.8	9	9.5	10
Nitrite as N	NA	NA	u	u	u	u
Nitrate as N	0.30	NA	0.3	0.3	0.3	0.22
Phosphate as P, ortho	NA	NA	u	u	u	u
Sulfate as SO4	9	NA	9.3	10	9.9	9.2
Ammonia as NH3-N	NA	NA	u	u	u	u
Alkalinity as CaCO3	5	NA	4	4	5	4
Carbon Dioxide (2)	68	65	83	95	66	95
Methane (2)	u	0.31	u	u	0.00	u
Ethane (2)	NA	u	u	u	0.002	u
Ethene (2)	NA	u	u	u	u	u
Propane (2)	NA	u	2.34	0.103	0.24	1.64
Total Organic Carbon	NA	NA	u	u	u	u
pH*	5.27	NA	5	4.8	4.7	5.01
Phosphate, total as P	NA	NA	u	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for MW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-1	3485-4	3563-5	3627-5	3776-6	3846-2	3995-6
Date	8/18/99	09/22/99	11/03/99	12/01/99	02/16/00	03/15/00	05/17/00
Total Heterotrophs	540	990	u	u	u	u	u
Specific Heterotrophs (1,2)*	180J	u	u	u	u	u	u

## Explanation:

All results shown in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value; compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for MW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-1	3485-4	3505-4	3542-3	3563-5	3608-4	3627-5	3677-3	3776-6	3846-2	3995-6	4131-5
Date	8/18/99	9/22/99	10/5/99	10/21/99	11/3/99	11/17/99	12/1/99	12/22/99	2/16/00	3/15/00	5/17/00	7/6/00
Iron	8,970	7,180	1,214	1,028	u	328	209	u	u	u	69	835
Iron (Dissolved)	5,030	3,190	411	601	u	u	u	u	u	93.8B	u	161

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J= Estimated value: compound detected below Practical Quantitation Limit



# Summary of Volatile Organic Compound Concentrations in MW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3422-2	3485-6	3505-6	3542-1	3563-8	3608-6	3627-6	3677-4	3776-07	3846-05	3995-7
Sampling Date	08/18/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
Dichlorodifluoromethane	5	U	U	U	5	U	U	U	5	U	U
Chloromethane	5	U	U	U	5	U	U	U	5	U	U
Vinyl Chloride	3	J	16	13	8	4	J	1	J	1	J
Bromomethane	5	U	U	U	5	U	U	U	5	U	U
Chloroethane	5	U	U	U	5	U	U	U	5	U	U
MTBE	5	U	U	U	5	U	U	U	5	U	U
Methylethyl ketone	10	U	U	U	10	U	U	U	5	U	U
Acetone	10	U	U	U	10	U	U	U	10	U	U
trichlorofluoromethane	5	U	U	U	5	U	U	U	10	U	U
1,1-dichloroethene	1	J	2	1	J	5	U	U	5	U	U
carbon disulfide	5	U	U	U	5	U	0.6	J	5	U	U
methylene chloride	5	U	U	U	5	U	U	U	5	U	U
trans-1,2-dichloroethene	5	U	U	U	5	U	0.6	J	5	U	U
1,1-dichloroethane	1	J	5	U	5	U	0.7	J	5	U	0.5
2,2-dichloropropane	5	U	U	U	5	U	U	U	5	U	U
chloroform	5	U	U	U	5	U	U	U	5	U	U
THF	10	U	U	U	10	U	U	U	10	U	U
bromochloromethane	5	U	U	U	5	U	U	U	5	U	U
1,1,1-trichloroethane	5	U	U	U	5	U	U	U	5	U	U
1,1-dichloropropene	5	U	U	U	5	U	U	U	5	U	U
carbon tetrachloride	5	U	U	U	5	U	U	U	5	U	U
1,2-dichloroethane	5	U	U	U	5	U	U	U	5	U	U
Benzene	5	U	U	U	5	U	U	U	5	U	U
trichloroethene	42	26	71	50	39	26	23	20	21	20	18
1,2-dichloropropane	5	U	U	U	5	U	U	U	5	U	U
dibromomethane	5	U	U	U	5	U	U	U	5	U	U
2-chlorovinyl ether	10	U	U	U	10	U	U	U	10	U	U
MIBK	10	U	U	U	10	U	U	U	10	U	U
Tetrachloroethene	13	14	49	31	24	14	13	11	13	10	10
Cis Dichloroethene	62	57	150	120	93	56	50	55	47	51	43
bromodichloromethane	5	U	U	U	5	U	U	U	5	U	U
trans-1,3-dichloropropene	5	U	U	U	5	U	U	U	5	U	U
toluene	5	U	U	U	5	U	U	U	5	U	U
cis-1,3-dichloropropene	5	U	U	U	5	U	U	U	5	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in MW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3422-2	3485-6	3505-6	3542-1	3563-8	3608-6	3627-6	3677-4	3776-07	3846-05	3995-7
Sampling Date	08/18/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
2-hexanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	5 U	10 U
1,1,2-trichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
dibromochloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dibromoethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
chlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
ethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,1,2-tetrachloroethane	5 U	5 U	50 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
m/p xylene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
o Xylene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
styrene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
isopropyl benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
bromoform	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,2,2-tetrachloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,3-trichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
n-propyl benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
bromobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3,5-trimethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-chlorotoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-chlorotoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
tert-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,4-trimethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
sec-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
p-isopropyltoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
n-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,4-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dibromo-3-chloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,4-trichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
hexachlorobutadiene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
naphthalene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,3-trichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for MW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-2	3485-6	3505-6	3542-1	3563-8	3608-6	3627-6	3627-7	3677-4	3776-7	3846-5	3995-7
Date	8/18/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
Chloride(1)	8.2	10.0	NA	NA	10	NA	11	11	NA	9.1	9.2	9.3
Nitrite as N	u	u	NA	NA	NA	NA	NA	NA	NA	u	u	u
Nitrate as N	0.1J	0.1J	NA	NA	u	NA	0.20	0.20	NA	0.2	0.3	0.2
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA	NA	NA	u	u	u
Sulfate as SO4	13	10	NA	NA	2.8	NA	3.8	3.7	NA	3.7	4.8	6.3
Ammonia as NH3-N	u	1.2	NA	NA	u	NA	NA	NA	NA	u	u	u
Alkalinity as CaCO3	12	15	NA	NA	8	NA	6	6	NA	6	5	4
Carbon Dioxide (2)	29	94	110	110	110	80	78	81	64	78	58	45
Methane (2)	0.21	0.21	0.61	0.33	0.19	0.02	u	u	0.01	u	u	0.00
Ethane (2)	u	u	u	u	u	u	NA	NA	u	u	u	u
Propane (2)	u	u	u	u	u	u	NA	NA	u	u	u	u
Total Organic Carbon	u	8	NA	NA	NA	NA	NA	NA	u	1.59	1.68	0.573
pH*	5.55	5.51	NA	NA	5.15	NA	5.25	5.27	NA	5.12	5.06	4.86
Phosphate, total as P	u	u	NA	NA	NA	NA	NA	NA	NA	u	u	u
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for MW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-02	3485-6	3563-8	3627-6	3776-07	3846-05	3995-7
Date	8/18/99	09/22/99	11/03/99	12/01/99	02/16/00	03/15/00	05/17/00
Total Heterotrophs	420	200J	u	u	u	u	u
Specific Heterotrophs (1,2)*	u	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for MW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-2	3485-6	3505-6	3542-1	3563-8	3608-6	3627-6	3677-4	3776-07	3846-05	3995-7
Date	08/18/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
Iron	9,150	5,250	3,544.9	1,629	201	166	141,000	u	58B	89.5B	658
Iron (Dissolved)	5,350	5,400	1,959.7	1,632	u	u	128,000	u	u	u	22

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL

# Summary of Volatile Organic Compound Concentrations in MW-7

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-5	3485-2	3505-2	3542-4	3563-6	3608-3	3627-4	3677-2	3776-05	3846-07	3995-4
Sampling Date	08/19/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
Dichlorodifluoromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Vinyl Chloride	2 J	7	5 J	4 J	3 J	2 J	1 J	1 J	1 J	5 U	5 U
Bromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	2 J
Chloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
MTBE	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Methylethyl ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	5 U	5 U
Acetone	5 U	10 U	4 J	10 U	10 U	10 U	10 U	10 U	10 U	5 U	10 U
trichlorofluoromethane	0 J	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	10 U	10 U
1,1-dichloroethene	5 U	5 U	5 U	5 U	5 U	0.6 J	5 U	5 U	5 U	5 U	5 U
carbon disulfide	10 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
methylene chloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,2-dichloroethene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloroethane	0 J	5 U	5 U	5 U	5 U	0.7 J	0.9 J	5 U	5 U	5 U	5 U
2,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	0.6 J	5 U	5 U	5 U	5 U
chloroform	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
THF	10 U	10 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
bromochloromethane	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	5 U	10 U
1,1,1-trichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
carbon tetrachloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trichloroethene	18	45	26	25	23	23	22	18	21	19	19
1,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
dibromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-chlorovinyl ether	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
MIBK	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	12	34	12	14	13	13	13	10	13	10	10
Cis Dichloroethene	41	110	53	55	53	50	46	47	47	48	44
bromodichloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
toluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
cis-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in MW-7

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-5	3485-2	3505-2	3542-4	3563-6	3608-3	3627-4	3677-2	3776-05	3846-07	3995-4
Sampling Date	08/19/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
2-hexanone	10	U	U	U	U	U	U	U	10	U	U
1,1,2-trichloroethane	5	U	U	U	U	U	U	U	5	U	U
1,3-dichloropropane	5	U	U	U	U	U	U	U	5	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	5	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	5	U	U
chlorobenzene	5	U	U	U	U	U	U	U	5	U	U
ethylbenzene	5	U	U	U	U	U	U	U	5	U	U
1,1,1,2-tetrachloroethane	5	U	U	U	U	U	U	U	5	U	U
m/p xylene	5	U	U	U	U	U	U	U	5	U	U
o Xylene	5	U	U	U	U	U	U	U	5	U	U
styrene	5	U	U	U	U	U	U	U	5	U	U
isopropyl benzene	5	U	U	U	U	U	U	U	5	U	U
bromoform	5	U	U	U	U	U	U	U	5	U	U
1,1,2,2-tetrachloroethane	5	U	U	U	U	U	U	U	5	U	U
1,2,3-trichloropropane	5	U	U	U	U	U	U	U	5	U	U
n-propyl benzene	5	U	U	U	U	U	U	U	5	U	U
bromobenzene	5	U	U	U	U	U	U	U	5	U	U
1,3,5-trimethylbenzene	5	U	U	U	U	U	U	U	5	U	U
2-chlorotoluene	5	U	U	U	U	U	U	U	5	U	U
4-chlorotoluene	5	U	U	U	U	U	U	U	5	U	U
tert-butylbenzene	5	U	U	U	U	U	U	U	5	U	U
1,2,4-trimethylbenzene	5	U	U	U	U	U	U	U	5	U	U
sec-butylbenzene	5	U	U	U	U	U	U	U	5	U	U
p-isopropyltoluene	5	U	U	U	U	U	U	U	5	U	U
1,3-dichlorobenzene	5	U	U	U	U	U	U	U	5	U	U
1,2-dichlorobenzene	5	U	U	U	U	U	U	U	5	U	U
n-butylbenzene	5	U	U	U	U	U	U	U	5	U	U
1,4-dichlorobenzene	5	U	U	U	U	U	U	U	5	U	U
1,2-dibromo-3-chloropropane	5	U	U	U	U	U	U	U	5	U	U
1,2,4-trichlorobenzene	5	U	U	U	U	U	U	U	5	U	U
hexachlorobutadiene	5	U	U	U	U	U	U	U	5	U	U
naphthalene	5	U	U	U	U	U	U	U	5	U	U
1,2,3-trichlorobenzene	5	U	U	U	U	U	U	U	5	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for MW-7

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-3	3485-2	3485-10	3505-2	3542-4	3563-6
Date	8/19/99	09/22/99	09/22/99	10/05/99	10/21/99	11/03/99
Chloride(1)	5.6	10.0	10.0	NA	NA	9.5
Nitrite as N	u	u	u	NA	NA	NA
Nitrate as N	0.2	0.1J	0.1J	NA	NA	0.2
Phosphate as P, ortho	u	u	u	NA	NA	NA
Sulfate as SO4	10	3.6	3.7	NA	NA	3.9
Ammonia as NH3-N	u	u	u	NA	NA	u
Alkalinity as CaCO3	11	5	9	NA	NA	8
Carbon Dioxide (2)	11	110	110	79	100	80
Methane (2)	0.20	0.34	0.48	0.17	0.15	u
Ethane (2)	u	u	u	u	u	u
Ethene (2)	u	u	u	u	u	u
Propane (2)	u	u	u	u	u	u
Total Organic Carbon	u	12	25	NA	NA	NA
pH*	5.55	5.12	5.13	NA	NA	5.3
Phosphate, total as P	0.04J	u	u	NA	NA	NA
Sulfide (1, applied)	NA	u	u	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter



# Summary of Limited Chemistry Analysis for MW-7

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3608-3	3627-4	3677-2	3776-5	3846-07	3995-4
Date	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
Chloride(1)	NA	11	NA	8.7	9.1	9.5
Nitrite as N	NA	NA	NA	u	u	u
Nitrate as N	NA	0.20	NA	0.2	0.3	0.2
Phosphate as P, ortho	NA	NA	NA	u	u	u
Sulfate as SO4	NA	5.2	NA	7.2	9.2	9.9
Ammonia as NH3-N	NA	NA	NA	u	u	u
Alkalinity as CaCO3	NA	7	NA	4	4	4
Carbon Dioxide (2)	71	78	77	64	78	53
Methane (2)	u	u	0.01	u	u	0.00
Ethane (2)	u	NA	u	u	u	u
Ethene (2)	u	NA	u	u	u	u
Propane (2)	u	NA	u	2.76	0.72	0.48
Total Organic Carbon	NA	NA	NA	u	u	u
pH*	NA	5.32	NA	5.04	4.92	4.81
Phosphate, total as P	NA	NA	NA	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for MW-7

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-03	3485-2	3485-10	3563-6	3627-4	3776-05	3846-07	3995-4
Date	8/19/99	09/22/99	09/22/99	11/03/99	12/01/99	02/16/00	03/15/00	05/17/00
Total Heterotrophs	420	240J	u	u	u	u	u	u
Specific Heterotrophs (1,2)*	190J	u	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for MW-7

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-5	3485-2	3485-10	3505-2	3542-4	3563-6	3608-3	3627-4	3677-2	3776-05	3846-07	3995-4
Date	08/19/99	09/22/99	09/22/99	10/05/99	10/21/99	11/03/99	11/17/99	12/01/99	12/22/99	02/16/00	03/15/00	05/17/00
Iron	5,210	410	371	2,657.10	195.00	u	178	u	u	u	275B	545
Iron (Dissolved)	4,490	352	284	402.01	675.00	u	u	u	u	u	u	u

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL

# Summary of Volatile Organic Compound Concentrations in MW-8

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3422-5	3485-5	3505-8	3537-3	3566-4	3611-1	3630-4	3677-5	3698-6	3776-8	3846-06	3995-8	4131-7
Sampling Date	08/18/99	09/22/99	10/05/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	01/12/00	02/16/00	03/15/00	05/17/00	07/08/00
Dichlorodifluoromethane	5	U	U	U	U	U	U	U	U	U	U	U	U
Chloromethane	5	U	U	U	U	U	U	U	U	U	U	U	U
Vinyl Chloride	1	J	4	J	4	J	2	J	1	J	1	J	J
Bromomethane	5	U	U	U	U	U	U	U	U	U	U	U	U
Chloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U
MTBE	5	U	U	U	U	U	U	U	U	U	U	U	U
Methylethyl ketone	10	U	U	U	U	U	U	U	U	U	U	U	U
Acetone	10	U	U	U	U	U	U	U	U	U	U	U	U
trichlorofluoromethane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,1-dichloroethene	0	U	U	U	U	U	U	U	U	U	U	U	U
carbon disulfide	5	U	U	U	U	U	U	U	U	U	U	U	U
methylene chloride	5	U	U	U	U	U	U	U	U	U	U	U	U
trans-1,2-dichloroethene	5	U	U	U	U	U	U	U	U	U	U	U	U
1,1-dichloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U
2,2-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U
chloroform	5	U	U	U	U	U	U	U	U	U	U	U	U
THF	10	U	U	U	U	U	U	U	U	U	U	U	U
bromochloromethane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,1,1-trichloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U
1,1-dichloropropene	5	U	U	U	U	U	U	U	U	U	U	U	U
carbon tetrachloride	5	U	U	U	U	U	U	U	U	U	U	U	U
1,2-dichloroethane	5	U	U	U	U	U	U	U	U	U	U	U	U
Benzene	5	U	U	U	U	U	U	U	U	U	U	U	U
trichloroethene	18	U	24	U	23	24	22	19	20	1	20	17	17
1,2-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U	U
tribromomethane	5	U	U	U	U	U	U	U	U	U	U	U	U
2-chlorovinyl ether	10	U	U	U	U	U	U	U	U	U	U	U	U
MIBK	10	U	U	U	U	U	U	U	U	U	U	U	U
Tetrachloroethene	2	J	11	19	13	13	12	11	12	12	10	10	10
Cis Dichloroethene	19	U	49	86	48	50	51	54	55	45	50	41	39
bromodichloromethane	5	U	U	U	U	U	U	U	U	U	U	U	U
trans-1,3-dichloropropene	5	U	U	U	U	U	U	U	U	U	U	U	U
toluene	5	U	U	U	U	U	U	U	U	U	U	U	U
cis-1,3-dichloropropene	5	U	U	U	U	U	U	U	U	U	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in MW-8

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3422-5	3485-5	3505-8	3537-3	3568-4	3611-1	3630-4	3677-5	3698-6	3776-08	3846-06	3995-8	4131-7
Sampling Date	08/18/99	09/22/99	10/05/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	01/12/00	02/16/00	03/15/00	05/17/00	07/06/00
2-hexanone	10	U	10	U	10	U	10	U	10	U	5	U	10
1,1,2-trichloroethane	5	U	5	U	5	U	5	U	5	U	5	U	5
1,3-dichloropropane	5	U	5	U	5	U	5	U	5	U	5	U	5
dibromochloromethane	5	U	5	U	5	U	5	U	5	U	5	U	5
1,2-dibromoethane	5	U	5	U	5	U	5	U	5	U	5	U	5
chlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
ethylbenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,1,1,2-tetrachloroethane	5	U	5	U	5	U	5	U	5	U	5	U	5
m/p xylene	5	U	20	5	U	5	U	5	U	5	U	5	U
o Xylene	5	U	5	U	5	U	5	U	5	U	5	U	5
styrene	5	U	5	U	5	U	5	U	5	U	5	U	5
isopropyl benzene	5	U	5	U	5	U	5	U	5	U	5	U	5
bromoform	5	U	5	U	5	U	5	U	5	U	5	U	5
1,1,2,2-tetrachloroethane	5	U	5	U	5	U	5	U	5	U	5	U	5
1,2,3-trichloropropane	5	U	5	U	5	U	5	U	5	U	5	U	5
n-propyl benzene	5	U	5	U	5	U	5	U	5	U	5	U	5
bromobenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,3,5-trimethylbenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
2-chlorotoluene	5	U	5	U	5	U	5	U	5	U	5	U	5
4-chlorotoluene	5	U	5	U	5	U	5	U	5	U	5	U	5
tert-butylbenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,2,4-trimethylbenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
sec-butylbenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
p-isopropyltoluene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,3-dichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,2-dichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
n-butylbenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,4-dichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,2-dibromo-3-chloropropane	5	U	5	U	5	U	5	U	5	U	5	U	5
1,2,4-trichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U	5
hexachlorobutadiene	5	U	5	U	5	U	5	U	5	U	5	U	5
naphthalene	5	U	5	U	5	U	5	U	5	U	5	U	5
1,2,3-trichlorobenzene	5	U	5	U	5	U	5	U	5	U	5	U	5

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for MW-8

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-03	3422-04	3485-5	3505-8	3537-3	3566-4	3611-1
Date	8/18/99	8/18/99	09/22/99	10/05/99	10/20/99	11/04/99	11/18/99
Chloride(1)	9.0	9.1	10.0	NA	NA	9.6	NA
Nitrite as N	u	u	u	NA	NA	NA	NA
Nitrate as N	0.3	0.3	0.3	NA	NA	0.2	NA
Phosphate as P, ortho	u	u	0.2	NA	NA	NA	NA
Sulfate as SO4	15	13	16	NA	NA	11	NA
Ammonia as NH3-N	u	u	1.6	NA	NA	0.7	NA
Alkalinity as CaCO3	12	9	9	NA	NA	5	NA
Carbon Dioxide (2)	16	16	79	100	94	82	77
Methane (2)	0.16	0.13	0.05	0.16	0.10	0.04	0.02
Ethane (2)	u	u	u	u	u	u	u
Ethene (2)	u	u	u	u	u	u	u
Propane (2)	u	u	u	u	u	u	u
Total Organic Carbon	u	u	15	NA	NA	NA	NA
pH*	5.61	5.65	5.29	NA	NA	5.47	NA
Phosphate, total as P	u	u	u	NA	NA	NA	NA
Sulfide (1, applied)	NA	NA	u	NA	NA	NA	NA

## Explanation:

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

pH\*=SU completed in laboratory

NA-Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for MW-8

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3630-4	3677-5	3698-6	3776-8	3846-6	3995-8	4131-7
Date	12/02/99	12/22/99	01/12/00	02/16/00	03/15/00	5/17/00	7/6/00
Chloride(1)	11	NA	9.3	8.7	9.1	9.5	10
Nitrite as N	NA	NA	u	u	u	u	u
Nitrate as N	0.30	NA	0.2	0.2	0.2	0.2	0.22
Phosphate as P, ortho	NA	NA	u	u	u	u	u
Sulfate as SO4	16	NA	28	9	9.7	9.2	8.4
Ammonia as NH3-N	NA	NA	0.5	u	u	u	u
Alkalinity as CaCO3	5	NA	4	4	4	6	4
Carbon Dioxide (2)	81	63	89	82	75	75	120
Methane (2)	u	0.01	u	u	u	0.004	u
Ethane (2)	NA	u	u	u	u	u	u
Ethene (2)	NA	u	u	u	u	u	u
Propane (2)	NA	u	u	2.17	0.93	0.404	1.15
Total Organic Carbon	NA	NA	u	u	u	u	u
pH*	4.99	NA	5.02	4.99	4.92	4.72	4.92
Phosphate, total as P	NA	NA	u	u	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA	NA

## Explanation:

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

pH\*=SU completed in laboratory

NA-Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for MW-8

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-03	3422-04	3485-5	3566-4	3630-4	3698-6	3698-8	3776-08	3846-06	3995-8	4131-7
Date	8/18/99	8/18/99	09/22/99	11/04/99	12/02/99	01/12/00	1/12/00	02/16/00	03/15/00	05/17/00	07/06/00
Total Heterotrophs	370	210J	300	u	u	u	240J	u	u	u	u
Specific Heterotrophs (1,2)*	170J	u	u	u	u	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs



# Summary of Metals Analysis for MW-8

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3422-5	3422-6	3485-5	3505-8	3537-3	3566-4	3611-1	3630-4	3677-5	3698-6	3776-08	3846-06	3995-8	4131-07
Date	08/18/99	08/18/99	09/22/99	10/05/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	01/12/00	02/16/00	03/15/00	05/17/00	07/06/00
Iron	4,870	5,340	2,450	444.59	83.80	u	u	u	u	52.5	283.0	u	63.6	244
Iron (Dissolved)	5,610	5,690	1,400	493.02	102.00	u	u	u	u	u	u	u	32.2	144

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL

# Summary of Volatile Organic Compound Concentration in Well LK

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3429-1	3485-1	3508-3	3537-1	3566-6	3611-3	3630-6	3677-7	3698-7	3782-02	3847-01	3995-10	4131-10
Sampling Date	08/20/99	09/22/99	10/06/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	01/12/00	02/17/00	03/16/00	05/17/00	07/08/00
Dichlorodifluoromethane	5	U	5	U	5	U	5	U	5	U	5	U	U
Chloromethane	5	U	5	U	5	U	5	U	5	U	5	U	U
Vinyl Chloride	4	J	6	U	4	J	3	J	4	J	10	3	J
Bromomethane	5	U	5	U	5	U	5	U	5	U	5	U	U
Chloroethane	5	U	5	U	5	U	5	U	5	U	5	U	U
MTBE	5	U	5	U	5	U	5	U	5	U	5	U	U
Methylethyl ketone	10	U	10	U	10	U	10	U	10	U	10	U	U
Acetone	8	J	10	U	10	U	10	U	10	U	10	U	U
trichlorofluoromethane	5	U	5	U	5	U	5	U	5	U	5	U	U
1,1-dichloroethene	2	J	5	U	5	U	5	U	5	U	5	U	U
carbon disulfide	5	U	5	U	5	U	5	U	5	U	5	U	U
methylene chloride	5	U	5	U	5	U	5	U	5	U	5	U	U
trans-1,2-dichloroethene	2	J	5	U	5	U	5	U	5	U	5	U	U
1,1-dichloroethane	1	J	5	U	5	U	5	U	5	U	5	U	U
2,2-dichloropropane	5	U	5	U	5	U	5	U	5	U	5	U	U
chloroform	5	U	5	U	5	U	5	U	5	U	5	U	U
THF	10	U	10	U	10	U	10	U	10	U	10	U	U
bromochloromethane	5	U	5	U	5	U	5	U	5	U	5	U	U
1,1,1-trichloroethane	5	U	5	U	5	U	5	U	5	U	5	U	U
1,1-dichloropropene	5	U	5	U	5	U	5	U	5	U	5	U	U
carbon tetrachloride	5	U	5	U	5	U	5	U	5	U	5	U	U
1,2-dichloroethane	5	U	5	U	5	U	5	U	5	U	5	U	U
Benzene	5	U	5	U	5	U	5	U	5	U	5	U	U
trichloroethene	90	130	220	U	10	J	0.8	J	5.0	U	1.0	J	5
1,2-dichloropropane	5	U	5	U	5	U	5	U	5	U	5	U	U
tribromomethane	5	U	5	U	5	U	5	U	5	U	5	U	U
2-chlorovinyl ether	10	U	10	U	10	U	10	U	10	U	10	U	U
MIBK	10	U	10	U	10	U	10	U	10	U	10	U	U
Tetrachloroethene	53	100	160	U	10	U	10	U	10	U	10	U	U
Cis Dichloroethene	210	400	610	D	140	150	140	160	D	170	D	16	U
bromodichloromethane	5	U	5	U	5	U	5	U	5	U	5	U	U
trans-1,3-dichloropropene	5	U	5	U	5	U	5	U	5	U	5	U	U
toluene	5	U	5	U	5	U	5	U	5	U	5	U	U
cis-1,3-dichloropropene	5	U	5	U	5	U	5	U	5	U	5	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit  
J - Compound Detected Below Laboratory Detection Limit  
D - Compounds identified in an analysis at a secondary dilution factor  
E - Estimated Value

# Summary of Volatile Organic Compound Concentration in Well LK

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3429-1	3485-1	3508-3	3537-1	3566-6	3611-3	3630-8	3677-7	3698-7	3782-02	3847-01	3995-10	4131-10
Sampling Date	08/20/99	09/22/99	10/06/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	01/12/00	02/17/00	03/16/00	05/17/00	07/06/00
2-hexanone	10	U	U	100	U	U	U	U	U	U	U	U	U
1,1,2-trichloroethane	5	U	U	50	U	U	U	U	U	U	U	U	U
1,3-dichloropropane	5	U	U	50	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	50	U	U	U	U	U	U	U	U	U
chlorobenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
ethylbenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,1,1,2-tetrachloroethane	5	U	U	50	U	U	U	U	U	U	U	U	U
m/p xylene	5	U	U	50	U	U	U	U	U	U	U	U	U
o Xylene	5	U	U	50	U	U	U	U	U	U	U	U	U
styrene	5	U	U	50	U	U	U	U	U	U	U	U	U
isopropyl benzene	5	U	U	50	U	U	U	U	U	U	U	U	U
bromoforn	5	U	U	50	U	U	U	U	U	U	U	U	U
1,1,2,2-tetrachloroethane	5	U	U	50	U	U	U	U	U	U	U	U	U
1,2,3-trichloropropane	5	U	U	50	U	U	U	U	U	U	U	U	U
n-propyl benzene	5	U	U	50	U	U	U	U	U	U	U	U	U
bromobenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,3,5-trimethylbenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
2-chlorotoluene	5	U	U	50	U	U	U	U	U	U	U	U	U
4-chlorotoluene	5	U	U	50	U	U	U	U	U	U	U	U	U
tert-butylbenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,2,4-trimethylbenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
sec-butylbenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
isopropyltoluene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,3-dichlorobenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,2-dichlorobenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
n-butylbenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,4-dichlorobenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,2-dibromo-3-chloropropane	5	U	U	50	U	U	U	U	U	U	U	U	U
1,2,4-trichlorobenzene	5	U	U	50	U	U	U	U	U	U	U	U	U
hexachlorobutadiene	5	U	U	50	U	U	U	U	U	U	U	U	U
naphthalene	5	U	U	50	U	U	U	U	U	U	U	U	U
1,2,3-trichlorobenzene	5	U	U	50	U	U	U	U	U	U	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

D - Compounds identified in an analysis at a secondary dilution factor

E - Estimated Value

# Summary of Limited Chemistry Analysis for Well LK

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3429-1	3485-1	3508-3	3537-1	3566-6	3611-3	3630-6
Date	8/20/99	09/22/99	10/05/99	10/20/99	11/04/99	11/18/99	12/02/99
Chloride(1)	6.7	10.0	NA	NA	11	NA	11
Nitrite as N	u	u	NA	NA	NA	NA	NA
Nitrate as N	0.1J	u	NA	NA	u	NA	u
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA
Sulfate as SO4	21	13	NA	NA	5.6	NA	7.4
Ammonia as NH3-N	u	u	NA	NA	1.2	NA	NA
Alkalinity as CaCO3	13	10	NA	NA	6	NA	6
Carbon Dioxide (2)	22	120	140	110	93	100	86
Methane (2)	0.34	0.27	0.68	0.51	0.01	0.05	0.46
Ethane (2)	u	u	u	u	u	u	NA
Ethene (2)	u	u	u	u	u	u	NA
Propane (2)	u	u	u	u	u	u	NA
Total Organic Carbon	u	11	NA	NA	NA	NA	NA
pH*	5.42	5.16	NA	NA	5.44	NA	5.16
Phosphate, total as P	0.04J	u	NA	NA	NA	NA	NA
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for Well LK

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3677-7	3698-7	3782-2	3847-1	3995-10	4131-10
Date	12/22/99	01/12/00	02/17/00	03/16/00	5/17/00	7/6/00
Chloride(1)	NA	11	11	11	11	11
Nitrite as N	NA	u	u	u	u	u
Nitrate as N	NA	u	0.1J	u	0.2	0.2
Phosphate as P, ortho	NA	u	u	u	u	u
Sulfate as SO4	NA	8.6	5.2	5	1.9	1.1
Ammonia as NH3-N	NA	0.7	1.3	0.9	u	0.4J
Alkalinity as CaCO3	NA	5	5	5	5	4
Carbon Dioxide (2)	79	140	120	120	68	59
Methane (2)	0.58	0.48	0.28	0.28	0.022	u
Ethane (2)	u	u	u	u	u	u
Ethene (2)	u	u	u	u	u	u
Propane (2)	u	u	0.066	0.27	0.138	1.75
Total Organic Carbon	NA	u	u	u	u	u
pH*	NA	4.87	5	4.88	4.64	4.9
Phosphate, total as P	NA	u	u	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value; compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for Well LK

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3429-1	3485-1	3566-6	3630-6	3698-7
Date	8/20/99	9/22/99	11/4/99	12/02/99	01/12/00
Total Heterotrophs	3,200	1,600	u	u	u
Specific Heterotrophs (1,2)*	1,300	380	u	u	u

Lab ID	3782-2	3847-1	3995-10	4131-10
Date	02/17/00	03/16/00	05/17/00	07/06/00
Total Heterotrophs	u	u	u	u
Specific Heterotrophs (1,2)*	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for Well LK

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3429-1	3485-1	3508-3	3537-1	3566-6	3611-3	3630-6	3677-7	3698-7	3782-02	3847-01	3995-10	4131-10
Date	08/20/99	09/22/99	10/06/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	01/12/00	02/17/00	03/16/00	05/17/00	07/06/00
Iron	7,330	4,060	879.6	763	462	238	278	249	110	222	962	294	888
Iron (Dissolved)	5,400	3,360	606.8	930	270	255	u	129	99.1B	155	472	176	447

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL

# Summary of Volatile Organic Compound Concentration in RW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-1	3508-5	3847-02	3995-11	4131-11
Sampling Date	08/19/99	10/06/99	03/16/00	05/17/00	07/06/00
Dichlorodifluoromethane	5	U	U	U	U
Chloromethane	5	U	U	U	U
Vinyl Chloride	4	J	1	2	J
Bromomethane	5	U	U	U	U
Chloroethane	5	U	U	U	U
MTBE	5	U	U	U	U
Methylethyl ketone	10	U	U	U	U
Acetone	10	U	U	U	U
trichlorofluoromethane	5	U	U	U	U
1,1-dichloroethene	5	U	U	U	U
carbon disulfide	5	U	U	U	U
methylene chloride	5	U	U	U	U
trans-1,2-dichloroethene	5	U	U	U	U
1,1-dichloroethane	5	U	U	U	U
2,2-dichloropropane	5	U	U	U	U
chloroform	5	U	U	U	U
THF	10	U	U	U	U
bromochloromethane	5	U	U	U	U
1,1,1-trichloroethane	5	U	U	U	U
1,1-dichloropropene	5	U	U	U	U
carbon tetrachloride	5	U	U	U	U
1,2-dichloroethane	5	U	U	U	U
Benzene	5	U	U	U	U
trichloroethene	29	26	16	16	15
1,2-dichloropropane	5	U	U	U	U
dibromomethane	5	U	U	U	U
2-chlorovinyl ether	10	U	U	U	U
MIBK	10	U	U	U	U
Tetrachloroethene	12	14	9	8	8
Cis Dichloroethene	66	56	45	42	35
bromodichloromethane	5	U	U	U	U
trans-1,3-dichloropropene	5	U	U	U	U
toluene	5	U	U	U	U
cis-1,3-dichloropropene	5	U	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit



# Summary of Volatile Organic Compound Concentration in RW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-1	3508-5	3847-02	3995-11	4131-11
Sampling Date	08/19/99	10/06/99	03/16/00	05/17/00	07/06/00
2-hexanone	10 U	10 U	10 U	10 U	10 U
1,1,2-trichloroethane	5 U	5 U	5 U	5 U	5 U
1,3-dichloropropane	5 U	5 U	5 U	5 U	5 U
dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,2-dibromoethane	5 U	5 U	5 U	5 U	5 U
chlorobenzene	5 U	5 U	5 U	5 U	5 U
ethylbenzene	5 U	5 U	5 U	5 U	5 U
1,1,1,2-tetrachloroethane	5 U	14	5 U	5 U	5 U
m/p xylene	5 U	5 U	5 U	5 U	5 U
o Xylene	5 U	5 U	5 U	5 U	5 U
styrene	5 U	5 U	5 U	5 U	5 U
isopropyl benzene	5 U	5 U	5 U	5 U	5 U
bromoform	5 U	5 U	5 U	5 U	5 U
1,1,2,2-tetrachloroethane	5 U	5 U	5 U	5 U	5 U
1,2,3-trichloropropane	5 U	5 U	5 U	5 U	5 U
n-propyl benzene	5 U	5 U	5 U	5 U	5 U
bromobenzene	5 U	5 U	5 U	5 U	5 U
1,3,5-trimethylbenzene	5 U	5 U	5 U	5 U	5 U
2-chlorotoluene	5 U	5 U	5 U	5 U	5 U
4-chlorotoluene	5 U	5 U	5 U	5 U	5 U
tert-butylbenzene	5 U	5 U	5 U	5 U	5 U
1,2,4-trimethylbenzene	5 U	5 U	5 U	5 U	5 U
sec-butylbenzene	5 U	5 U	5 U	5 U	5 U
p-isopropyltoluene	5 U	5 U	5 U	5 U	5 U
1,3-dichlorobenzene	5 U	5 U	5 U	5 U	5 U
1,2-dichlorobenzene	5 U	5 U	5 U	5 U	5 U
n-butylbenzene	5 U	5 U	5 U	5 U	5 U
1,4-dichlorobenzene	5 U	5 U	5 U	5 U	5 U
1,2-dibromo-3-chloropropane	5 U	5 U	5 U	5 U	5 U
1,2,4-trichlorobenzene	5 U	5 U	5 U	5 U	5 U
hexachlorobutadiene	5 U	5 U	5 U	5 U	5 U
naphthalene	5 U	5 U	5 U	5 U	5 U
1,2,3-trichlorobenzene	5 U	5 U	5 U	5 U	5 U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for RW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-1	3508-5	3750-1	3847-2	3995-11	4131-11
Date	8/19/99	10/06/99	02/02/00	03/16/00	05/17/00	07/06/00
Chloride(1)	17.0	NA	NA	9.2	9.5	10
Nitrite as N	u	NA	NA	u	u	u
Nitrate as N	0.5	NA	NA	0.3	0.3	0.3
Phosphate as P, ortho	u	NA	NA	u	u	u
Sulfate as SO4	10	NA	NA	11	9.5	9.8
Ammonia as NH3-N	u	NA	NA	1	u	0.56
Alkalinity as CaCO3	6.8	NA	NA	8	10	7
Carbon Dioxide (2)	23	83	NA	49	34	87
Methane (2)	0.28	0.22	NA	0.03	0.04	u
Ethane (2)	u	u	NA	u	u	u
Ethene (2)	u	u	NA	u	u	u
Propane (2)	u	u	1.14	0.374	0.208	2.27
Total Organic Carbon	u	NA	NA	u	u	u
pH*	5.37	NA	NA	5.26	5.07	5.18
Phosphate, total as P	u	NA	NA	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

Summary of Heterotroph Analysis for RW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-1	3847-2	4131-11
Date	8/19/99	03/16/00	07/06/00
Total Heterotrophs	u	u	u
Specific Heterotrophs (1,2)*	u	u	u

Explanation:  
All results in cfu/mL  
u = Result was below the instrument detection limit  
J= Estimated value: compound detected above Practical Quantitation Limit  
Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for RW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-1	3508-5	3847-02	3995-11	4131-11
Date	08/19/99	10/06/99	03/16/00	05/17/00	07/06/00
Iron	3,070	4,299.0	2,490	2,580	5,090
Iron (Dissolved)	2,930	3,950.6	2,200	2,430	5,440

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL

# Summary of Volatile Organic Compound Concentrations in OW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-2	3481-5	3505-3	3532-2	3561-2	3606-2	3625-2	3673-2	3773-05	3842-01	3987-5
Sampling Date	08/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/15/00	03/14/00	05/16/00
Dichlorodifluoromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Vinyl Chloride	1 J	4 J	5 J	5 J	4 J	2 J	2 J	1 J	1 J	1 J	1 J
Bromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
MTBE	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Methylethyl ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	5 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
trichlorofluoromethane	1 J	5 J	5 J	5 J	5 J	5 J	5 J	5 J	5 J	5 J	5 J
1,1-dichloroethene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
carbon disulfide	10 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
methylene chloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,2-dichloroethene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-dichloroethane	2 J	5 J	5 J	5 J	5 J	0.7 J	0.6 J	5 J	0.6 J	5 J	5 J
2,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
chloroform	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
THF	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
bromochloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,1-trichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,1-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
carbon tetrachloride	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U	0.8 U	0.6 U	5 U	5 U	5 U	5 U
trichloroethene	30 U	21 U	27 U	25 U	25 U	22 U	22 U	18 U	21 U	21 U	21 U
1,2-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
tribromomethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-chlorovinyl ether	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
MIBK	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	2 J	7 J	13 J	14 J	13 J	12 J	12 J	10 J	13 J	11 J	12 J
Cis Dichloroethene	23 U	41 U	57 U	60 U	58 U	48 U	46 U	50 U	46 U	51 U	42 U
bromodichloromethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
trans-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
toluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
cis-1,3-dichloropropene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in OW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-2	3481-5	3505-3	3532-2	3561-2	3606-2	3625-2	3673-2	3773-05	3842-01	3987-5
Sampling Date	08/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/15/00	03/14/00	05/16/00
2-hexanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	5 U	5 U
1,1,2-trichloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3-dichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dibromoethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
chlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
ethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,1,2-tetrachloroethane	5 U	5 U	13 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
m/p xylene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
o Xylene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
styrene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
isopropyl benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
bromoform	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,2,2-tetrachloroethane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,3-trichloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
n-propyl benzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
bromobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3,5-trimethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-chlorotoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-chlorotoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
tert-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,4-trimethylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
sec-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
p-isopropyltoluene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,3-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
n-butylbenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,4-dichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-dibromo-3-chloropropane	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,4-trichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
hexachlorobutadiene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
naphthalene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2,3-trichlorobenzene	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for OW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-2	3481-5	3505-3	3532-2	3561-2	3606-2
Date	8/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99
Chloride(1)	4.7	8.9	NA	NA	1.9	NA
Nitrite as N	u	u	NA	NA	NA	NA
Nitrate as N	u	0.2	NA	NA	0.8	NA
Phosphate as P, ortho	u	u	NA	NA	NA	NA
Sulfate as SO4	20	10	NA	NA	13	NA
Ammonia as NH3-N	u	u	NA	NA	u	NA
Alkalinity as CaCO3	25	16	NA	NA	9	NA
Carbon Dioxide (2)	36	92	84	81	31	66
Methane (2)	0.23	0.28	0.21	0.15	0.01	0.02
Ethane (2)	u	u	u	u	u	u
Ethene (2)	u	u	u	u	u	u
Propane (2)	u	u	u	u	u	u
Total Organic Carbon	2J	15	NA	NA	NA	NA
pH*	5.94	5.81	NA	NA	5.73	NA
Phosphate, total as P	0.05	u	NA	NA	NA	NA
Sulfide (1, applied)	NA	u	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for OW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3625-2	3673-2	3773-5	3842-1	3987-5
Date	11/30/99	12/21/99	02/15/00	03/14/00	05/16/00
Chloride(1)	11	NA	8.5	9.4	9.3
Nitrite as N	NA	NA	u	u	u
Nitrate as N	u	NA	u	0.1J	u
Phosphate as P, ortho	NA	NA	u	u	u
Sulfate as SO4	8.4	NA	7.8	8.4	8.3
Ammonia as NH3-N	NA	NA	u	0.9	u
Alkalinity as CaCO3	12	NA	7	5	6
Carbon Dioxide (2)	68	46	81	86	53
Methane (2)	0.017	0.02	u	u	0.00
Ethane (2)	NA	u	u	u	0.013
Ethene (2)	NA	u	u	u	u
Propane (2)	NA	u	2.8	0.472	1.68
Total Organic Carbon	NA	NA	u	u	u
pH*	5.58	NA	5.22	5.57	4.97
Phosphate, total as P	NA	NA	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

,NA - Sample not analyzed for this parameter



# Summary of Heterotroph Analysis for OW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-2	3481-5	3561-2	3625-2	3773-5	3842-1	3995-11
Date	8/19/99	09/21/99	11/02/99	11/30/99	02/15/00	03/14/00	05/17/00
Total Heterotrophs	880	1000	u	u	u	u	u
Specific Heterotrophs (1,2)*	160J	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for OW-1

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-2	3481-5	3505-3	3532-2	3561-2	3606-2	3625-2	3673-2	3773-05	3842-01	3987-05
Date	08/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	2/15/00	03/14/00	05/16/00
Iron	15,400	10,700	17,660	6,301.1	5,830	6,330	5,070	3,880	2,020	1,920	1,670
Iron (Dissolved)	18,700	u	9,608.3	6,025.7	3,930	3,590	4,980	3,620	1,890	1,440	634

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL

# Summary of Volatile Organic Compound Concentrations in OW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-8	3481-4	3505-5	3532-3	3561-3	3606-3	3625-3	3673-3	3776-01	3842-05	3987-6	4131-08
Sampling Date	08/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/16/00	03/14/00	05/16/00	07/06/00
Dichlorodifluoromethane	5	U	5	U	5	U	5	U	5	U	5	U
Chloromethane	5	U	5	U	5	U	5	U	5	U	5	U
Vinyl Chloride	5	U	5	U	5	U	2	U	1	U	5	U
Bromomethane	5	U	5	U	5	U	5	U	5	U	5	U
Chloroethane	5	U	5	U	5	U	5	U	5	U	5	U
MTBE	5	U	5	U	5	U	5	U	5	U	5	U
Methylethyl ketone	10	U	10	U	10	U	10	U	10	U	10	U
Acetone	10	U	10	U	10	U	10	U	10	U	10	U
trichlorofluoromethane	5	U	5	U	5	U	5	U	5	U	5	U
1,1-dichloroethene	5	U	5	U	5	U	0.5	U	5	U	5	U
carbon disulfide	5	U	5	U	5	U	5	U	5	U	5	U
methylene chloride	5	U	5	U	5	U	5	U	5	U	5	U
trans-1,2-dichloroethene	5	U	5	U	5	U	5	U	5	U	5	U
1,1-dichloroethane	5	U	5	U	5	U	0.7	U	0.7	U	5	U
2,2-dichloropropane	5	U	5	U	5	U	5	U	5	U	5	U
chloroform	5	U	5	U	5	U	5	U	5	U	5	U
THF	10	U	10	U	10	U	10	U	10	U	10	U
bromochloromethane	5	U	5	U	5	U	5	U	5	U	5	U
1,1,1-trichloroethane	5	U	5	U	5	U	5	U	5	U	5	U
1,1-dichloropropene	5	U	5	U	5	U	5	U	5	U	5	U
carbon tetrachloride	5	U	5	U	5	U	5	U	5	U	5	U
1,2-dichloroethane	5	U	5	U	5	U	5	U	5	U	5	U
Benzene	5	U	5	U	5	U	0.8	U	5	U	5	U
trichloroethene	5	U	2	U	2	U	20	U	21	U	9	U
1,2-dichloropropane	5	U	5	U	5	U	5	U	5	U	5	U
tribromomethane	5	U	5	U	5	U	5	U	5	U	5	U
2-chlorovinyl ether	10	U	10	U	10	U	10	U	10	U	10	U
MIBK	10	U	10	U	10	U	10	U	10	U	10	U
Tetrachloroethene	5	U	5	U	5	U	11	U	13	U	5	U
Cis Dichloroethene	5	U	4	U	3	U	40	U	44	U	15	U
bromodichloromethane	5	U	5	U	5	U	5	U	5	U	5	U
trans-1,3-dichloropropene	5	U	5	U	5	U	5	U	5	U	5	U
toluene	5	U	5	U	5	U	5	U	5	U	5	U
cis-1,3-dichloropropene	5	U	5	U	5	U	5	U	5	U	5	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in OW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3426-8	3481-4	3505-5	3532-3	3561-3	3606-3	3625-3	3673-3	3776-01	3842-05	3987-6	4131-08
Sampling Date	08/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/16/00	03/14/00	05/16/00	07/06/00
2-hexanone	10	U	U	U	U	U	U	U	U	U	U	U
1,1,2-trichloroethane	5	U	U	U	U	U	U	U	U	U	U	U
1,3-dichloropropane	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	U	U	U	U	U	U	U	U	U	U
chlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
ethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,1,1,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U
m/p xylene	5	U	U	U	U	U	U	U	U	U	U	U
o Xylene	5	U	U	U	U	U	U	U	U	U	U	U
styrene	5	U	U	U	U	U	U	U	U	U	U	U
Isopropyl benzene	5	U	U	U	U	U	U	U	U	U	U	U
bromoform	5	U	U	U	U	U	U	U	U	U	U	U
1,1,2,2-tetrachloroethane	5	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichloropropane	5	U	U	U	U	U	U	U	U	U	U	U
n-propyl benzene	5	U	U	U	U	U	U	U	U	U	U	U
bromobenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,3,5-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
2-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U
4-chlorotoluene	5	U	U	U	U	U	U	U	U	U	U	U
tert-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trimethylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
sec-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
p-isopropyltoluene	5	U	U	U	U	U	U	U	U	U	U	U
1,3-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
n-butylbenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,4-dichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
1,2-dibromo-3-chloropropane	5	U	U	U	U	U	U	U	U	U	U	U
1,2,4-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U
hexachlorobutadiene	5	U	U	U	U	U	U	U	U	U	U	U
naphthalene	5	U	U	U	U	U	U	U	U	U	U	U
1,2,3-trichlorobenzene	5	U	U	U	U	U	U	U	U	U	U	U

All Results in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for OW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-8	3481-4	3505-5	3532-3	3561-3	3606-3	3625-3
Date	8/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99
Chloride(1)	6.0	5.7	NA	NA	1.9	NA	8.8
Nitrite as N	u	u	NA	NA	NA	NA	NA
Nitrate as N	0.9	0.9	NA	NA	0.8	NA	0.40
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA
Sulfate as SO4	22	17	NA	NA	13	NA	15
Ammonia as NH3-N	u	1.2	NA	NA	u	NA	NA
Alkalinity as CaCO3	2	7	NA	NA	9	NA	15
Carbon Dioxide (2)	23	52	55	38	31	39	52
Methane (2)	u	u	0.01	0.17	0.01	0.01	u
Ethane (2)	u	u	u	u	u	u	NA
Ethene (2)	u	u	u	u	u	u	NA
Propane (2)	u	u	u	u	u	u	NA
Total Organic Carbon	u	u	NA	NA	NA	NA	NA
pH*	4.6	5.37	NA	NA	5.73	NA	5.78
Phosphate, total as P	0.14	u	NA	NA	NA	NA	NA
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for OW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3673-3	3750-2	3776-1	3842-5	3987-6	4131-8
Date	12/21/99	02/02/00	02/16/00	03/14/00	5/16/00	7/6/00
Chloride(1)	NA	NA	9.2	9.5	5	6.4
Nitrite as N	NA	NA	u	u	u	u
Nitrate as N	NA	NA	0.3	0.3	1	1.6
Phosphate as P, ortho	NA	NA	u	u	u	u
Sulfate as SO4	NA	NA	10	12	11	8.3
Ammonia as NH3-N	NA	NA	u	u	u	0.4J
Alkalinity as CaCO3	NA	NA	15	13	6	3
Carbon Dioxide (2)	27	NA	82	110	46	78
Methane (2)	0.01	NA	u	u	u	u
Ethane (2)	u	NA	u	u	u	u
Ethene (2)	u	NA	u	u	u	u
Propane (2)	u	u	u	0.472	0.035	0.92
Total Organic Carbon	NA	NA	u	u	u	0.4J
pH*	NA	NA	5.65	5.57	5.51	4.94
Phosphate, total as P	NA	NA	u	u	u	0.1
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for OW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-8	3481-4	3561-3	3625-3	3776-1	3842-5	3987-6	4131-8
Date	8/19/99	09/21/99	11/02/99	11/30/99	02/16/00	03/14/00	05/16/00	7/6/00
Total Heterotrophs	7,600	210J	2,000	U	U	U	U	U
Specific Heterotrophs (1,2)*	1,600	U	500	U	U	U	U	U

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals Analysis for OW-5

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3426-8	3481-4	3505-5	3532-3	3561-3	3606-3	3625-3	3673-3	3776-01	3842-05	3987-06	4131-08
Date	08/19/99	09/21/99	10/05/99	10/19/99	11/02/99	11/16/99	11/30/99	12/21/99	02/16/00	03/14/00	05/16/00	07/06/00
Iron	u	u	u	21.85	333	164	u	u	u	50.8B	u	165
Iron (Dissolved)	57.5B	10,300	u	20.03	75.5B	u	u	u	u	ug/l	u	223

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL



# Summary of Volatile Organic Compound Concentrations in OW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3429-2	3485-3	3508-2	3537-2	3566-5	3611-2	3630-5	3677-6	3782-01	3846-01	3995-9
Sampling Date	08/20/99	09/22/99	10/06/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	02/17/00	03/15/00	05/17/00
Dichlorodifluoromethane	5	U	5	U	U	U	U	U	U	U	U
Chloromethane	5	U	5	U	U	U	U	U	U	U	U
Vinyl Chloride	1	J	6	J	J	2	J	1	J	1	J
Bromomethane	5	U	5	U	U	U	U	U	U	U	U
Chloroethane	5	U	5	U	U	U	U	U	U	U	U
MTBE	5	U	5	U	U	U	U	U	U	U	U
Methylethyl ketone	10	U	10	U	U	U	U	U	U	U	U
Acetone	10	U	10	U	U	U	U	U	U	U	U
trichlorofluoromethane	5	U	5	U	U	U	U	U	U	U	U
1,1-dichloroethene	5	U	5	U	U	U	U	U	U	U	U
carbon disulfide	5	U	5	U	U	U	U	U	U	U	U
methylene chloride	5	U	5	U	U	U	U	U	U	U	U
trans-1,2-dichloroethene	5	U	5	U	U	U	U	U	U	U	U
1,1-dichloroethane	5	U	5	U	U	U	U	U	U	U	U
2,2-dichloropropane	5	U	5	U	U	U	U	U	U	U	U
chloroform	5	U	5	U	U	U	U	U	U	U	U
THF	10	U	10	U	U	U	U	U	U	U	U
bromochloromethane	5	U	5	U	U	U	U	U	U	U	U
1,1,1-trichloroethane	5	U	5	U	U	U	U	U	U	U	U
1,1,1-dichloropropene	5	U	5	U	U	U	U	U	U	U	U
carbon tetrachloride	5	U	5	U	U	U	U	U	U	U	U
1,2-dichloroethane	5	U	5	U	U	U	U	U	U	U	U
Benzene	5	U	5	U	U	U	U	U	U	U	U
trichloroethene	25	U	27	U	25	22	22	21	21	21	18
1,2-dichloropropane	5	U	5	U	U	U	U	U	U	U	U
tribromomethane	5	U	5	U	U	U	U	U	U	U	U
2-chlorovinyl ether	10	U	10	U	U	U	U	U	U	U	U
MIBK	10	U	10	U	U	U	U	U	U	U	U
Tetrachloroethene	3	J	13	U	15	12	13	11	12	11	10
Cis Dichloroethene	25	U	55	U	52	46	51	48	48	53	43
bromodichloromethane	5	U	5	U	U	U	U	U	U	U	U
trans-1,3-dichloropropene	5	U	5	U	U	U	U	U	U	U	U
toluene	5	U	5	U	U	U	U	U	U	U	U
cis-1,3-dichloropropene	5	U	5	U	U	U	U	U	U	U	U

All Results are in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Volatile Organic Compound Concentrations in OW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Laboratory Sample Number	3429-2	3485-3	3508-2	3537-2	3566-5	3611-2	3630-5	3677-6	3782-01	3846-01	3995-9
Sampling Date	08/20/99	09/22/99	10/06/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	02/17/00	03/15/00	05/17/00
2-hexanone	10	U	U	U	U	U	U	U	U	U	U
1,1,2-trichloroethane	5	U	5	U	U	U	U	U	U	U	U
1,3-dichloropropane	5	U	5	U	U	U	U	U	U	U	U
dibromochloromethane	5	U	5	U	U	U	U	U	U	U	U
1,2-dibromoethane	5	U	5	U	U	U	U	U	U	U	U
chlorobenzene	5	U	5	U	U	U	U	U	U	U	U
ethylbenzene	5	U	5	U	U	U	U	U	U	U	U
1,1,1,2-tetrachloroethane	5	U	5	U	U	U	U	U	U	U	U
m/p xylene	5	U	14	U	U	U	U	U	U	U	U
o Xylene	5	U	5	U	U	U	U	U	U	U	U
styrene	5	U	5	U	U	U	U	U	U	U	U
isopropyl benzene	5	U	5	U	U	U	U	U	U	U	U
bromoform	5	U	5	U	U	U	U	U	U	U	U
1,1,2,2-tetrachloroethane	5	U	5	U	U	U	U	U	U	U	U
1,2,3-trichloropropane	5	U	5	U	U	U	U	U	U	U	U
n-propyl benzene	5	U	5	U	U	U	U	U	U	U	U
bromobenzene	5	U	5	U	U	U	U	U	U	U	U
1,3,5-trimethylbenzene	5	U	5	U	U	U	U	U	U	U	U
2-chlorotoluene	5	U	5	U	U	U	U	U	U	U	U
4-chlorotoluene	5	U	5	U	U	U	U	U	U	U	U
tert-butylbenzene	5	U	5	U	U	U	U	U	U	U	U
1,2,4-trimethylbenzene	5	U	5	U	U	U	U	U	U	U	U
sec-butylbenzene	5	U	5	U	U	U	U	U	U	U	U
p-isopropyltoluene	5	U	5	U	U	U	U	U	U	U	U
1,3-dichlorobenzene	5	U	5	U	U	U	U	U	U	U	U
1,2-dichlorobenzene	5	U	5	U	U	U	U	U	U	U	U
n-butylbenzene	5	U	5	U	U	U	U	U	U	U	U
1,4-dichlorobenzene	5	U	5	U	U	U	U	U	U	U	U
1,2-dibromo-3-chloropropane	5	U	5	U	U	U	U	U	U	U	U
1,2,4-trichlorobenzene	5	U	5	U	U	U	U	U	U	U	U
hexachlorobutadiene	5	U	5	U	U	U	U	U	U	U	U
naphthalene	5	U	5	U	U	U	U	U	U	U	U
1,2,3-trichlorobenzene	5	U	5	U	U	U	U	U	U	U	U

All Results are in ug/L

U - Compound Not Detected Above Laboratory Detection Limit

J - Compound Detected Below Laboratory Detection Limit

# Summary of Limited Chemistry Analysis for OW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3429-2	3485-3	3508-2	3537-2	3566-5	3611-2	3630-5
Date	8/20/99	09/22/99	10/05/99	10/20/99	11/04/99	11/18/99	12/02/99
Chloride(1)	6.4	9.5	NA	NA	9.5	NA	10
Nitrite as N	u	u	NA	NA	NA	NA	NA
Nitrate as N	u	0.1J	NA	NA	u	NA	u
Phosphate as P, ortho	u	u	NA	NA	NA	NA	NA
Sulfate as SO4	23	18	NA	NA	8.6	NA	9
Ammonia as NH3-N	u	u	NA	NA	0.9	NA	NA
Alkalinity as CaCO3	17	10	NA	NA	10	NA	9
Carbon Dioxide (2)	32	83	75	75	80	66	46
Methane (2)	0.16	0.18	0.21	0.17	0.04	0.03	0.008
Ethane (2)	u	u	u	u	u	u	NA
Ethene (2)	u	u	u	u	u	u	5.47
Propane (2)	u	u	u	u	u	u	NA
Total Organic Carbon	u	20	NA	NA	NA	NA	NA
pH*	5.72	5.58	NA	NA	5.76	NA	NA
Phosphate, total as P	u	u	NA	NA	NA	NA	NA
Sulfide (1, applied)	NA	u	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Limited Chemistry Analysis for OW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3677-6	3782-1	3782-3	3846-1	3995-9	3995-5
Date	12/22/99	02/17/00	02/17/00	03/15/00	5/17/00	5/17/00
Chloride(1)	NA	9.1	8.9	9.1	9.5	9.5
Nitrite as N	NA	u	u	u	u	u
Nitrate as N	NA	0.1J	0.4	0.1J	u	0.3
Phosphate as P, ortho	NA	u	u	u	u	u
Sulfate as SO4	NA	8.3	8.1	8.6	9.1	10
Ammonia as NH3-N	NA	1.9	0.7	u	u	u
Alkalinity as CaCO3	NA	7	6	4	5	4
Carbon Dioxide (2)	57	66	61	80	56	59
Methane (2)	0.02	u	u	u	0.003	0.004
Ethane (2)	u	u	u	u	u	0.002
Ethene (2)	u	u	u	u	u	u
Propane (2)	u	2	1.17	0.59	0.492	0.38
Total Organic Carbon	NA	u	u	u	u	u
pH*	NA	5.48	5.04	5.18	4.8	4.64
Phosphate, total as P	NA	u	u	u	u	u
Sulfide (1, applied)	NA	NA	NA	NA	NA	NA

## Explanation:

Concentrations listed in mg/L

u - Result was below the instrument detection limit

J - Estimated value: compound detected above Practical Quantitation Limit

pH\* - SU completed in laboratory

NA - Sample not analyzed for this parameter

# Summary of Heterotroph Analysis for OW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3429-2	3563-7	3481-2	3627-3	3698-5	698-8 (DU)	3776-4	3846-3	3987-9	4131-4
Date	8/20/99	11/3/99	9/21/99	12/01/99	01/12/00	01/12/00	02/16/00	03/15/00	05/16/00	7/6/00
Total Heterotrophs	90,000	u	u	540	u	240J	u	u	u	u
Specific Heterotrophs (1,2)*	7,400	u	u	u	u	u	u	u	u	u

## Explanation:

All results in cfu/mL

u = Result was below the instrument detection limit

J= Estimated value: compound detected above Practical Quantitation Limit

Specific Heterotrophs (1,2)\* = propanotrophs

# Summary of Metals for OW-6

Naval Air Engineering Station  
Lakehurst, New Jersey

Lab ID	3429-2	3485-3	3508-2	3537-2	3566-5	3611-2	3630-5	3677-6	3782-01	3782-03	3846-01	3995-9
Date	08/20/99	09/22/99	10/06/99	10/20/99	11/04/99	11/18/99	12/02/99	12/22/99	02/17/00	2/17/00	03/15/00	05/17/00
Iron	9,420	5,770	4,288	3,537	2,820	2,670	2,410	2,300	1,650	1,580	1,350	635
Iron (Dissolved)	9,170	5,920	4,150	2,368	1,720	2,780	2,370	1,740	1,540	1,580	1,250	556

## Explanation:

All results in ug/L

u = Result was below the instrument detection limit

J = Estimated value: compound detected below Practical Quantitation Limit

B = Detected between MDL and RL